GEOGRAPHIC VARIATION IN SLASH PINE
(*Pinus elliottii* Engelm.)

By

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INTRODUCTION

When a plant species occurs over a wide geographic range, individuals or populations growing in different localities frequently display differences in one or more traits. This phenotypic variation associated with locality (geographic variation) may be due to environmental or genetic factors, or interactions between them.

Environmental differences are a consequence of modifications caused by habitat factors. Genetic variation associated with locality (racial variation), on the other hand, is due to such mechanisms as mutation, natural selection, hybridization, or combinations of these factors. It basically results from the fact that the individuals within populations differ genetically. The genetic heterogeneity between individuals is caused by mutation or hybridization. It is maintained by intricate mechanisms inherent in most species, enhancing chances of survival of the species in a constantly changing environment. This genetic variation among individuals is the basis for racial variation.

If the localities are characterized by different environments, and if some degree of reproductive isolation is present, racial variation will occur. Plants that are genetically most suited to their particular habitat will survive and reproduce in greater numbers than those not so well endowed. Some degree of reproductive isolation is necessary because if interbreeding occurs randomly throughout a species range, natural selection in a given locality would merely result in a change in the mean of the whole species. In forest trees, sufficient isolation is provided by the limited distance of pollen and seed dispersal.

Although natural selection is the most important cause of racial variation, it is believed that such variation may also result from chance fluctuations in gene frequencies (genetic drift) leading to fixation of genes. Genetic drift is most apt to occur in small, isolated populations and environmental differences need not be present.

Geographic variation occurs in characteristic patterns, depending upon the nature of the forces that caused it. Since climatic factors are often important natural selection forces, and since climate often changes gradually over a species range, the pattern of racial variation frequently is continuous or clinal. However, relatively uniform and discontinuous habitats may cause relatively discrete populations or ecotypes. Likewise, present or past isolation may cause ecotypes or combinations of both clinal and ecotypic variation.

Needless to say, geographic variation in forest trees is common, and it is of great interest to forest land managers and forest scientists. The nature of geographic variation (i.e., the proportion of environmental and genetic components) is important to land managers because if differences in economically important traits are genetic they must use care in selecting sources of seed for forest planting. Likewise, forest geneticists are keenly aware of the possibilities of capitalizing on racial variation in development of superior strains. Taxonomists are interested in patterns of variation in their attempts to classify trees on both the species and subspecies level.

The present study was designed mainly to investigate the nature and patterns of geographic and racial variation for a number of characteristics in slash pine (<u>Pinus</u> <u>elliottii</u> Engelm.), one of the

more important commercial trees of the Southeast. Secondary objectives were (1) to search for causes of patterns of variation that might be found, and (2) to compare the magnitude of variation associated with localities against that associated with individuals within localities.

REVIEW OF LITERATURE

General

It is probably safe to say that geographic variation has been studied in all commercially important forest tree species and in many of the noncommercially important ones. Langlet (1938) summarized much of the early work. Several recent publications include brief reviews of much of the past literature: Dorman (1952), Critchfield (1957), Echols (1958), Squillace and Bingham (1958), Callaham (1962), and Langlet (1963).

These studies have demonstrated that racial variation is prevalent in forest trees, although some species such as red pine (*P. resinosa* Ait.) showed no, or relatively small, variation in some traits (Buckman and Buchman, 1962; and Wright *et al*., 1963). As might be expected, differences were found to be greatest, or most prevalent, where the species range covered a large geographic area, such as ponderosa pine (*P. ponderosa* Laws.) and Scotch pine (*P. sylvestris* L.). However, variation has been found even in trees having a relatively small geographic range, such as sand pine (*P. clausa* (Chapm.) Vasey)(Little and Dorman, 1952a), and western white pine (*P. monticola* Dougl.) (Squillace and Bingham, 1958).

Many of the patterns reported contained an element of continuous or clinal variation. Where the variation is a result of gradual changes in climatic or geographic features, and where complete reproductive isolation is absent, one might, of course, expect the variation in plant characteristics to be continuous. Stebbins (1950, p. 44) expressed the opinion that most species with a continuous range, encompassing changes in latitude or climate, will be found to possess clines for physiological characteristics adapting them to conditions prevailing in various parts of their range. Numerous patterns showing continuous variation associated with rainfall have been reported (Larson, 1957; Thorbjornsen, 1961; Goddard and Strickland, 1962; and Squillace and Silen, 1962). Elevational trends were reported by Callaham and Liddicoet (1961) and Critchfield (1957). Numerous instances of gradual changes associated with latitude or length of photoperiod have been found (Langlet, 1936; and Schoenike and Brown, 1963).

One frequently also sees in the literature evidences of ecotypic patterns of variation (for examples, see Wright, 1944; Pauley and Perry, 1954; Vaartaja, 1954; Squillace and Bingham, 1958; and Wells, 1962). However, some of these authors used the term broadly, applying it to patterns which are genetic and adaptive but not necessarily discontinuous. Too, there is often some question as to whether the ecotypic variation occurs exclusive of other types.

Theoretically, distinct ecotypes with no element of continuity can occur in a species having geographical isolation, and in which genetic adaptation to a uniform habitat (such as soil or exposure) has occurred. However, since the habitat within a species range or within parts of a species range often varies continuously, combinations of patterns are more likely. Thus, it is possible to visualize a situation in which a species occurs in geographically isolated groups, with ecotypic variation occurring among groups as a result of adaptation or genetic drift, or both. But with the climate varying continuously through the range we could have clinal variation occurring both within and between the ecotypes. This may indeed be the situation in some species such as ponderosa pine, in which elevational gradients were reported by Callaham and Liddicoet (1961), and in which ecotypes were delineated by Wells (1962). In this same species, Squillace and Silen (1962) pointed out apparent clinal variation associated with climatic variables but acknowledged that likelihood that discontinuities also occurred; irregularities in a clinal pattern were illustrated by Callaham and Hasel (1961). Clausen _et al_. (1948) found clinal trends for height of plant between climatic races of _Achillea lanulosa_. In Scotch pine, Wright and Baldwin (1957) and Wright and Bull (1963) delineated broad ecotypes within the species range, while Langlet (1936) pointed out that clinal variation for certain characteristics occur both within and between ecotypes of this species.

The existence or nonexistence of the two kinds of variation often becomes a matter of degree, with interpretation highly subject to the opinions of the investigator and confused by terminology. It is no wonder that considerable discussion and debate have resulted on this problem (Turesson, 1936; Faegri, 1937; Langlet, 1936, 1959, and 1963; Kriebel, 1956; and Callaham, 1962). Until more concrete terminology and guidelines for classification are available (if indeed ever) the wise investigator will describe his pattern of variation as best he can without attempting to classify it categorically (Langlet, 1963).

Another type of variation noted rather frequently in the literature is random variation. Here differences among stands sampled within the species range may be real but exhibit no distinctive geographical trends or patterns such as clines or ecotypes. This type of variation is likely to occur where the species range is discontinuous in the present or had been so at some time in the recent past, as exemplified by the random pattern found in the major portion of the range of European black pine (*Pinus nigra* Arnold) by Wright and Bull (1962). However, random differences have been found for seed germination in slash pine by Mergen and Hoekstra (1954). Likewise, Thorbjornsen (1961) reported random variation for wing length, seed length, cone length, needle length, and frequency of serrations on needle margins in loblolly pine (*P. taeda* L.). Both of these species have rather continuous ranges. The cause of random variations in such cases is obscure, although partial reproductive isolation which is believed to be common in most trees may have a bearing (Wright, 1943).

Slash Pine

Slash pine, like many pine species, has suffered a confused nomenclature (Little and Dorman, 1954). Recently, these authors (1952b) subdivided it into two varieties, *P. elliottii* Engelm. var. *elliottii*, typical slash pine, and *P. elliottii* var. *densa* Little and Dorman, South Florida slash pine, formally publishing a description of the latter.

The ranges of the two varieties, as given by Little and Dorman (1954), are shown in Figure 1. The authors showed the varieties as being allopatric, the boundary between them being indicated by the heavy dashed line in central Florida. At a later date, Langdon (1963) published a revised range of the *densa* variety, extending it northward a considerable distance as shown by the dotted line in Figure 1. He indicated that trees of both varieties occur in the area of overlap. Slash pine does not extend into the Caribbean Islands.

Features which, according to Little and Dorman (1954), distinguish the two varieties are as follows:

Var. *elliottii*: Needles in fascicles of two and three, and normal seedlings with erect, slender, pencillike stems.

Var. *densa*: Needles in fascicles of two (infrequently three); seedling with grasslike, almost stemless stage with many crowded needles, and thick tap root. The wood of this variety is also heavier and has thicker summerwood than the typical variety.

Mature trees of the two varieties also differ somewhat in general appearance. Variety *densa* is normally shorter, with its stem often forking into large branches and its crown being generally flat-topped and open, compared to the usually taller and relatively narrow-crowned typical variety. However, according to many foresters, these differences

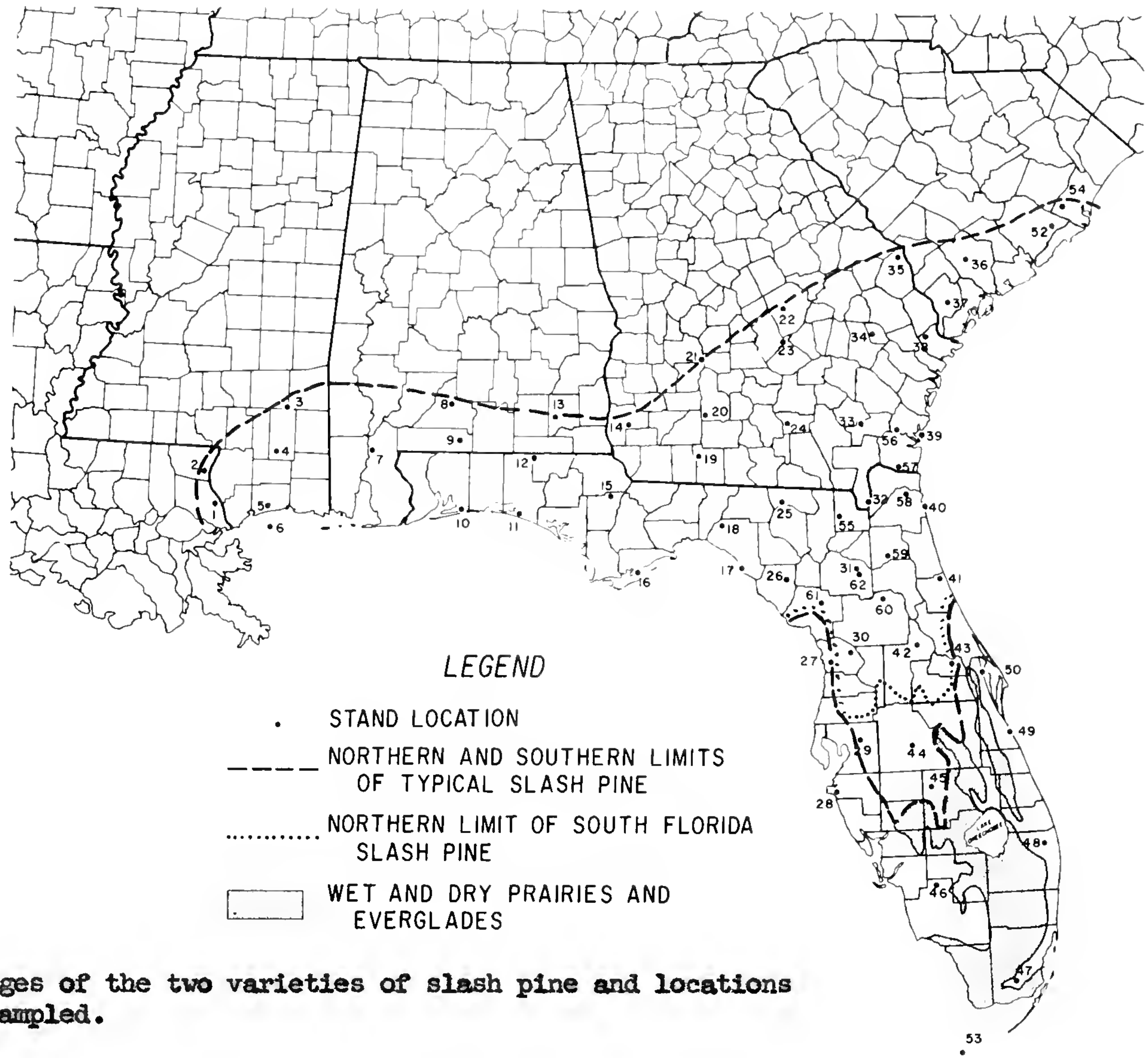


Figure 1.--Ranges of the two varieties of slash pine and locations of stands sampled.

and even the more distinctive seedling characteristics become obscure in the portions of the species range where the two varieties meet, making it difficult or impossible to separate the two varieties.

Slash pine, being relatively susceptible to fire injury, was originally confined to ponds, pond margins, and other wet areas (Cooper, 1957). With the advent of white man and fire protection it has invaded drier areas, where it grows sympatrically with the relatively fire resistant longleaf pine (P. palustris Mill.).

South Florida slash pine occurs in pure stands on flatwoods sites in the southern part of its range, while to the north it is confined to the wetter sites along streams and in other poorly drained or swampy areas (Langdon, 1963). In the southern portion of its range, there is some degree of geographic isolation between the two coastal areas, caused by the Everglades. The two "prongs" along the coast, however, meet in Polk and Osceola Counties.

A number of seed source studies (studies in which seeds were collected from trees growing in different portions of the species range and planted in a common environment) have been conducted with slash pine. Some of these sampled only the northern portion of the species range (Table 1), while others sampled a relatively broad latitudinal zone (Table 2). The studies were designed mainly to determine variation within the range of elliottii only. However, sampling in some studies of the latter group (Table 2) extended as far south as Polk County, Florida, which is in the area bordering the two varieties (transition zone). In the "Florida-Georgia" experiment (Table 2), a single source well within the range of densa (Collier County, Florida) was included

Table 1.--Summary of slash pine seed source tests which sampled a relatively narrow latitudinal zone

Location of test, and authors	Seed sources	Age of test (in field)	Traits showing significant differences	Traits not showing significant differences
	Number	Years		
Alexandria, La.	7			
Derr and Dell (1960); Derr and Enghardt (1960)		22		Growth and fusiform rust[a]
Echols (1960)		21		Stemwood specific gravity and tracheid length
Barrett (1962, 1963a, 1963b)		24		Oleoresin yield, exudation pressure, viscosity, and exudation pressure/viscosity
South Africa (4 localities)	8			
Sherry (1947)		9		Height, d.b.h., and tree form, in most localities.
Harrison Exptl. Forest, Miss.	5			
Echols (1960)		14		Stemwood specific gravity and tracheid length
N.E. Miss. Exptl. Forest, Miss.	6			
Switzer (1959)		11	11-year survival, height, d.b.h., and volume	1-3 year survival
Santee Exptl. Forest, S. C.	6			
Bethune (1960)		12	Height	Survival, d.b.h., and fusiform rust[a]
Morgan County, Ga.	5			
Greene (1962)		3		Survival, height, and fusiform rust[a]

[a] *Cronartium fusiforme* (Hedgc. and Hunt)

Table 2.--Summary of slash pine seed source tests which sampled a relatively wide latitudinal zone

Location of test, and authors	Seed sources	Age of test (in field)	Traits showing significant differences	Traits not showing significant differences
	Number	Years		
"Southwide" (12 localities)	5-6			
Mergen (1954)		2	Height in one locality	
Henry (1959)		5	Fusiform rust[a], in one locality	Fusiform rust[a], in four localities
Wakeley (1955, 1959, 1961)		5	Survival, in 71% of the localities and height in 29% of the localities	Survival in 29% of the localities and height in 71% of the localities
Florida-Georgia (7 localities)	15			
Mergen and Hoekstra (1954)		(Nursery)	Seed yield and germination	
Mergen (1958)		(Nursery	Resin ducts, and stomata per mm.	Frequency of serrations on needles and number of rows of stomata
Langdon (1958a)		3	Survival, height, and tip moth[b] damage in one locality	
Squillace and Kraus (1959)		3	Height and survival (averages over all localities)	
Australia (3 localities)	13			
Nikles (1962)		6		Slight differences in growth

a *Cronartium fusiforme* (Hedgc. and Hunt)

b *Rhyacionia* spp.

along with elliottii sources in one of the seven plantations in the test, but was not included in the statistical tests indicated.

As seen in Tables 1 and 2, significant differences were found more frequently in those studies sampling a broad latitudinal zone than in those sampling only the northern part of the species range. This was especially true for growth rate. In one experiment, latitudinal growth rate differences were mainly due to a sample from Polk County, Florida, in the transition zone and results suggested the existence of natural hybridization between varieties in that area (Mergen, 1954; and Wakeley, 1959). (For further evidences of hybridization see Mergen, 1958.) In still another experiment, growth rate was usually moderately superior among sources from extreme south Georgia and north Florida (north-central region), and it decreased both to the north and south of this area (Squillace and Kraus, 1959). These authors suggested that climatic conditions may be optimum in the north-central region, where superior growth rate may have resulted from relatively strong natural selection for this trait. Resistance to cold damage in the northern fringe and unfavorable distribution of rainfall in the southern areas may have been relatively more important than growth rate in natural selection in these areas.

The results for survival were similar to those for growth rate--differences were found more frequently when a broad latitudinal zone was sampled than when only the northern portion of the species range was sampled. In both the "Southwide" and the "Florida-Georgia" studies early survival was usually greater among northern sources than among southern ones. Some traits, such as stomatal frequency (Mergen, 1958)

and fusiform rust resistance (Henry, 1959), showed evidences of longitudinal variation in the north.

Several studies other than seed source tests, have also provided information on geographic variation in slash pine. A plantation near Gainesville, Florida, containing clones from phenotypically superior trees selected in various portions of the range of elliottii (Perry and Wang, 1955) showed differences in gum yielding ability at about 7 years of age (Anonymous, 1962, p. 124). A cattle damage test in south Florida, comparing the two varieties of slash pine, showed significant differences in growth and survival (Hilmon, et al., 1962). Stemwood specific gravity and/or summerwood per cent were studied in elliottii trees growing in their natural habitats by several investigators (Larson, 1957; Perry and Wang, 1958; Wheeler and Mitchell, 1959 and 1962; and Goddard and Strickland, 1962). These studies agreed in showing that specific gravity and summerwood per cent increase in going from north to south through Georgia and Florida, and from west to east through the northern portion of the species range. The clinal pattern of variation was shown to be closely associated with seasonal distribution of rainfall, in addition to latitude and longitude. However, the two experiments reported upon by Echols (1960), shown in Table 1, suggest that the pattern in these wood properties is largely environmental rather than genetic. Variation in time of pollen and seed ripening has been reported by Dorman and Barber (1956).

As noted earlier, the above studies dealt mainly with variety elliottii. The possibility of variation within variety densa seems to have escaped study.

BASIS FOR VARIATION IN SLASH PINE

This section contains an examination of the environmental factors which may have been instrumental in causing geographic and/or racial variation to be reported. Information on climate was freely drawn from U.S. Weather Bureau reports (Weather Bureau, 1956 and 1959).

Climate within the range of slash pine varies from a zone of transition between temperate and subtropical conditions in the north to tropical conditions in the Florida Keys. Temperature variation and other factors are strongly affected by latitude and proximity to the Atlantic Ocean or Gulf of Mexico. Summers are relatively long, warm, and humid; winters are relatively mild due to the southerly latitude and warm adjacent sea waters, but periodically cool and cold air from the north invades the region.

Mean January temperatures increase gradually from a low of about 50°F. at the northern extreme in South Carolina to a high of about 70°F. in the Florida Keys (Fig. 2). No such gradient occurs in summer, however, mean July temperatures averaging about 80°-82°F. throughout the region. Length of frost-free season increases from a low of about 240 days at the northern extremes to a high of 365 days in south Florida. The spread between daily maximum and minimum temperature is greatly affected by proximity to the sea, especially during the growing season. For example, the mean spread for the months of April through September varies from as little as 14°F. along the coasts to as high as 26°F. in interior portions of the species range (Fig. 3).

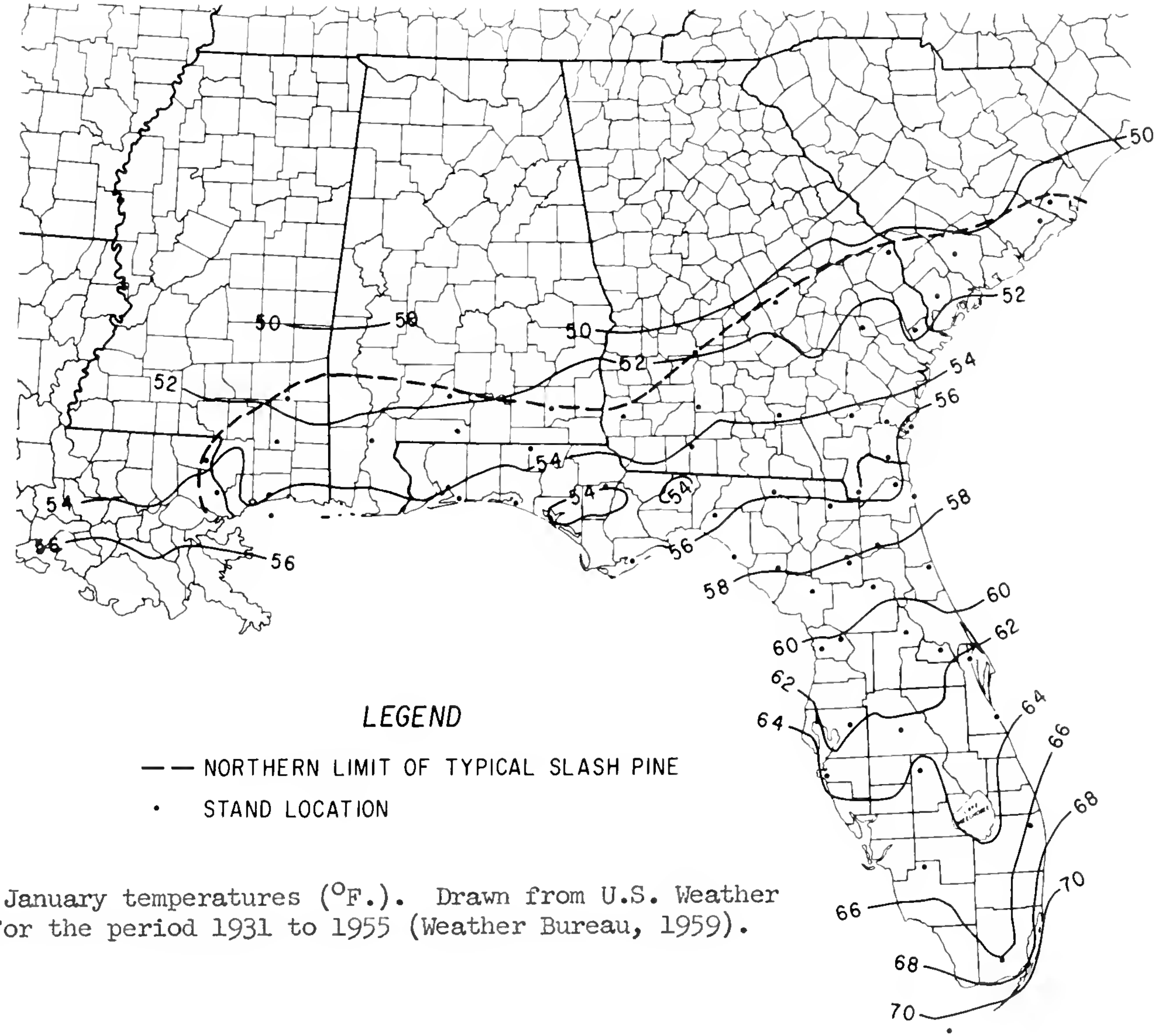


Figure 2.--Mean January temperatures (^{o}F.). Drawn from U.S. Weather Bureau data for the period 1931 to 1955 (Weather Bureau, 1959).

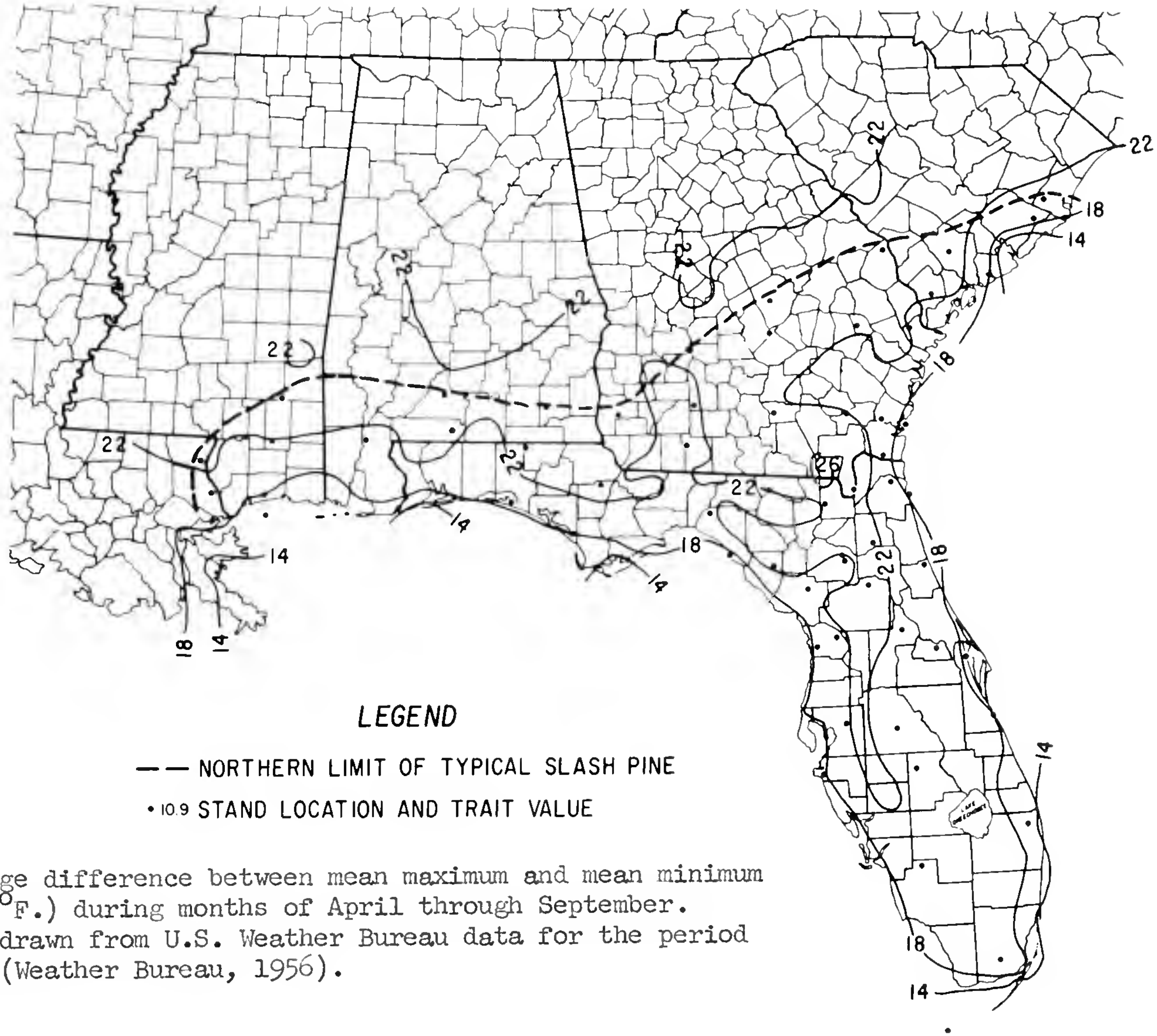


Figure 3.--Average difference between mean maximum and mean minimum temperature (°F.) during months of April through September. Compiled and drawn from U.S. Weather Bureau data for the period 1931 to 1952 (Weather Bureau, 1956).

Mean annual precipitation varies from as high as 64 inches in southeast Florida and southern Louisiana and Mississippi, to as low as 44 inches at the northern limits in east Georgia (Fig. 4). Although the pattern is somewhat erratic there is a general tendency for decreasing rainfall from southern Louisiana, east and northeast to South Carolina, and from south Florida northward.

Seasonal distribution of rainfall shows distinctive patterns. Precipitation is distributed favorably in the northern portion of the species range, with highs occurring generally in February and March, and July and August. In the south, most of the total rainfall occurs in the midsummer months and wintertime drouths are rather common. The variation expressed in these terms produces continuous patterns. These are well illustrated in maps drawn by Squillace and Kraus (1959) which show patterns of rainfall for January through April, and June through September. The same situation is also expressed in Figure 5 which shows isograms for rainfall from October through May as a per cent of annual. Note that it is low in extreme southwest Florida and increases rather uniformly to the north and northwest.

Estimates of precipitation-evaporation (P-E) ratios were determined for weather stations within the range of slash pine, using the method described by Thornthwaite (1931.) These ratios are measures of precipitation effectiveness and are estimated from mean monthly precipitation and mean monthly temperature, utilizing Thornthwaite's formula or his nomogram. (The latter, a graphical method, was used for the present study). P-E ratios were determined for months of February, March, and April, and summed. These months were chosen because effective rainfall during this period may be more closely

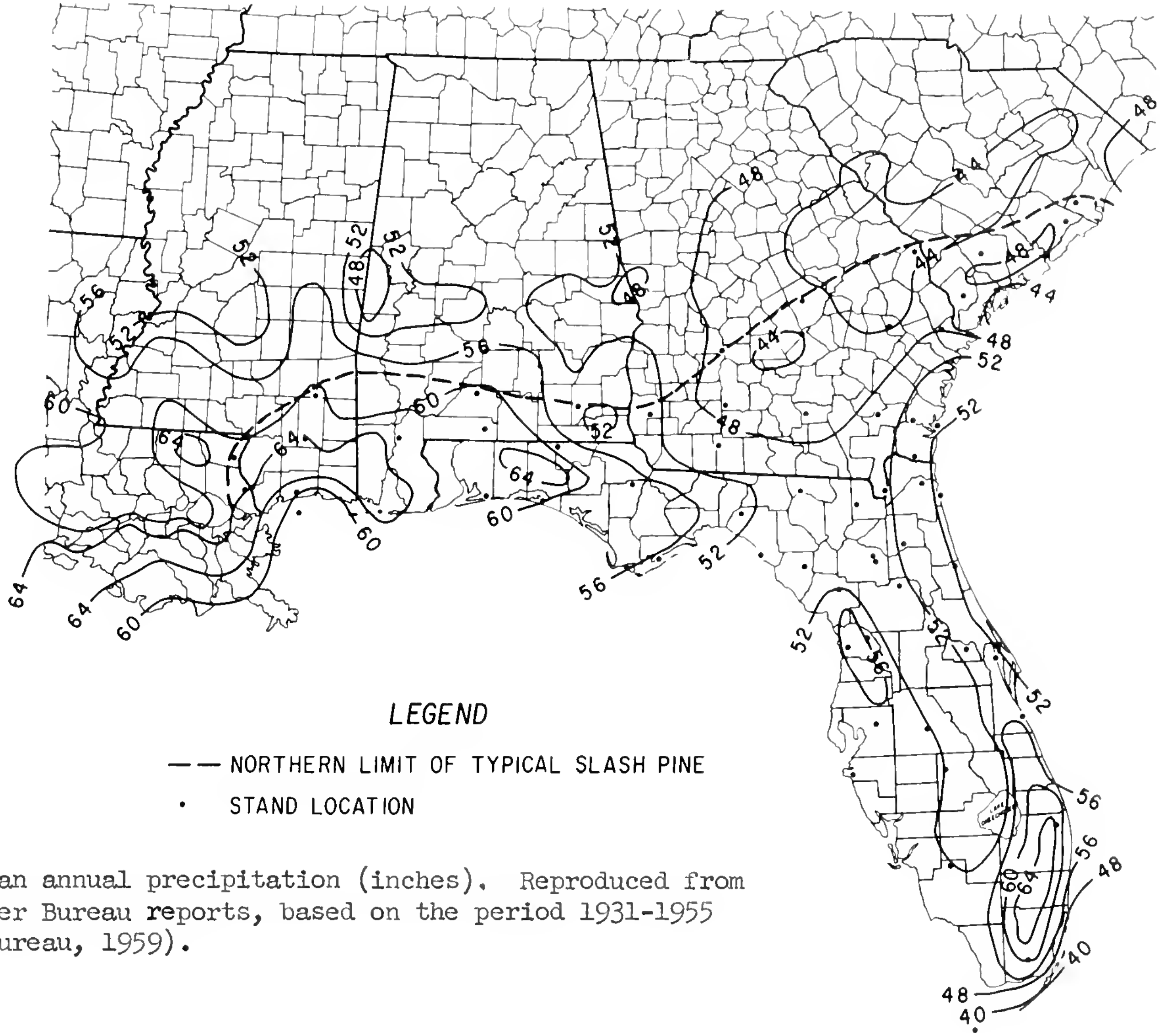


Figure 4.--Mean annual precipitation (inches). Reproduced from U.S. Weather Bureau reports, based on the period 1931-1955 (Weather Bureau, 1959).

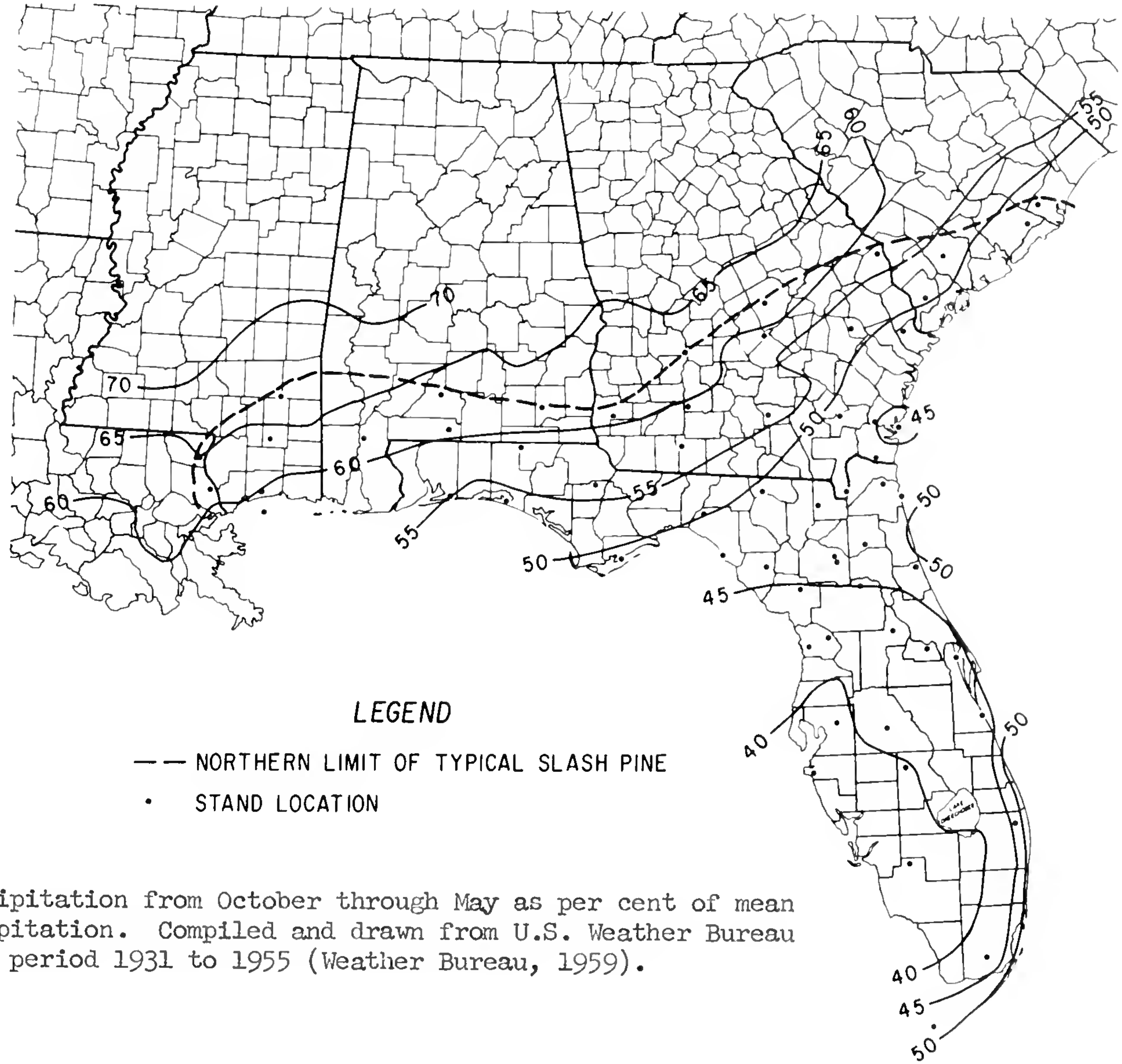


Figure 5.--Precipitation from October through May as per cent of mean annual precipitation. Compiled and drawn from U.S. Weather Bureau data for the period 1931 to 1955 (Weather Bureau, 1959).

associated with growth of slash pine than rainfall during other periods, as reported by Coile (1936). The data showed a distinctive, continuous pattern (Fig. 6), much like that for October-May precipitation per cent.

Hurricanes are common along the coastal areas (Weather Bureau, 1959). Chances of hurricane force winds are greatest at the southern tip of Florida, and the probabilities generally decrease to the north along the Atlantic coast to southeast Georgia where they increase slightly. On the Gulf coast, probabilities decrease northward to the Tampa region but then become high again in west Florida and south Alabama.

Soils within the range of slash pine are for the most part sandy in texture, and low in mineral nutrients and moisture holding capacity. They are often underlain with hardpans 18 to 24 inches below the surface. Coastal areas are low and flat while the interior portions are generally rolling, with gentle hills and ridges mostly under 200 feet in elevation but reaching as high as 345 feet in Florida, and 600 feet in Georgia. Local variations in soil characteristics, frequently associated with small differences in elevation (as little as several feet), are common. These variations strongly affect tree growth (Cooper, 1957).

Forest geneticists are concerned as to whether or not racial differences associated with local variations in soils are present. Edaphic races have been reported for some species of plants (Snaydon and Bradshaw, 1961). Most workers feel that this type of variation has not developed in slash pine. Until recently, slash pine occurred only on pond margins. Natural selection probably has not had sufficient time to cause appreciable changes in gene frequencies on the higher areas, especially since these areas frequently are interspersed with flatwoods.

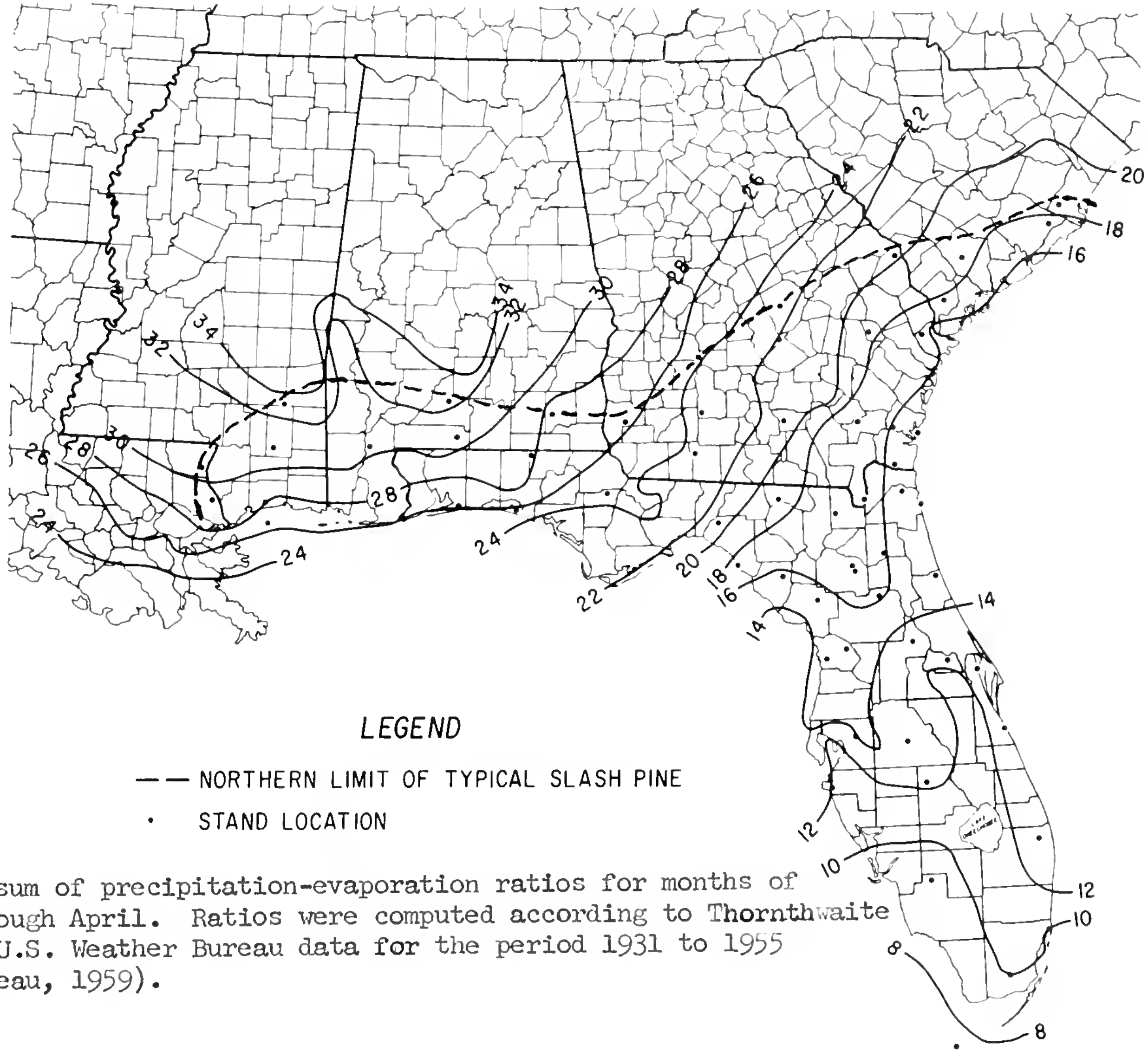


Figure 6.--The sum of precipitation-evaporation ratios for months of February through April. Ratios were computed according to Thornthwaite (1931) from U.S. Weather Bureau data for the period 1931 to 1955 (Weather Bureau, 1959).

Geological changes during the Pleistocene period (beginning about 3/4 million years ago) undoubtedly had some bearing on the development of variation in slash pine. Following the Kansan glaciation, the Florida peninsula was reduced to a group of small islands extending from Hamilton County in the north to as far as Highlands County in the south (MacNeil, 1950). The second shoreline recognized by MacNeil, following the Illinoian glaciation, shows a similar group of islands but they were larger and the mainland extended as far south as Alachua County. During the mid-Wisconsin glacial recession, much of Florida occurred as part of the mainland, the peninsula extending as far south as Glades County, with a number of islands mostly along the east and southwest coasts. The final and most recent shoreline recognized by MacNeil was of post-Wisconsin origin. Although the degree of inundation was relatively small at this time, a number of islands occurred along coastal regions.

PROCEDURE

Parental Material

The conventional seed source technique was used for this study but with the additional features of: (1) sampling parental materials to measure geographic variation, and (2) maintaining individual mother tree identity in order to study mother tree variation within stands.

In the fall of 1960, mature cones and foliage samples were collected from each of five (in a few instances less) mother trees at each of 55 stands scattered throughout the range of slash pine. Proposed stand locations were predesignated mainly by gridding the area on a map, with a spacing interval of about 50 miles. However, irregularity of the species range, non-forested areas, and other considerations necessitated moving many of the proposed locations so that the actual distribution of the stands only faintly resembles a grid (Fig. 1).

It should be noted that systematic sampling of stands leads to a bias in variance and the magnitude of this bias is unknown. An alternative procedure would have been to sample stands completely at random or to stratify and sample randomly within strata. Systematic sampling was chosen because of a strong desire to include the extremities of the range, and because it was felt that this method would be most suitable for elucidating patterns of variation.

Materials were collected through the aid of cooperators. Instructions included selection of accessible, natural stands as near as feasible to the predesignated points, with the requirements that they (1) be at least 400 feet away from flowering slash pine plantations, (2) be of fruiting age, and (3) not be selected for any particular traits.

Within each stand, mother trees were selected randomly but with restrictions that (1) they be dominants or codominants, possessing mature cones, (2) they be at least 200 but not more than 1,300 feet apart, and (3) they have one or more neighbors within 100 feet. In those areas where the two varieties meet or overlap (transition zone), no attempt was made to select one or the other variety, because (1) identification of the varieties in the mature stage is difficult, as noted earlier, and (2) it was felt that attempted selection would prevent the possibility of determining the population structure of the transition zone. Mother trees within stands were designated "A" through "E". These letters, combined with stand numbers (1 through 55), served to identify all mother trees.

From each tree, 10 to 15 cones and 5 branch shoots were collected from the upper and outer portions of the crowns. Most of the materials were obtained by shooting them out of the trees with a rifle. Plant materials were sent to Olustee, Florida, for processing.

Collections were highly successful but, upon receipt of the materials, the sample from stand 51 was found to be loblolly pine rather than slash pine (identification was verified upon sowing of seed). Hence, this stand was discarded. Also, materials for three mother trees (29E, 48A, and 48C) were missing. Finally, it was later determined that mother tree 21D was apparently a hybrid (or backcross) between slash and longleaf pines, and hence data from this tree were eliminated from analyses. These circumstances reduced the number of stands to 54, and mother trees to 266.

In the late fall of 1960, after cone collection, seven additional stands were designated (numbers 56 through 62) and used for collection of foliage samples (see Fig. 1 for location of these). These supplementary samples were taken mainly to check on what appeared to be unusual results from the main samples and to increase sampling intensity in north Florida. Data from the supplemental samples were not used in statistical analyses but were included with data from main samples in elucidating patterns of variation.

Upon receipt, the unopened cones were counted and 10 (or less when a shortage occurred) were selected from each mother tree and photographed. The negatives were then projected on a microfilm reader and the lengths and diameters (across broadest portion) of each cone were measured. Cones were dried in the open air; then the seeds were extracted and winnowed with a seed blower which removed practically all empty seed. Full seed were then counted, weighed, and stored in a refrigerator at approximately 40°F. until planted.

Branch shoots were handled as follows: Eight fascicles were taken randomly from the central portion of the first flush of the 1960 increment of each branch shoot (40 fascicles per mother tree). The number of needles per fascicle was determined on each of these. Then 3 fascicles were selected randomly from each group of 8 samples (15 per mother tree), and on these the lengths of fascicles and the lengths of the fascicle sheaths were measured. Finally, 2 additional needles were selected from each shoot, again from the central portion of the first 1960 flush of growth (10 per mother tree) and the uppermost 2 inches of each was cut and preserved in formalin-aceto-ethyl alcohol fluid.

The preserved needle specimens were then used for additional measurements as follows: The lower 1/8-inch of each section was cut and examined under a binocular dissecting microscope (45X) and the following measurements taken: (1) Width of the needle, measured across the flat surface or surfaces (binate needles had one flat surface while ternate needles had two), using an eyepiece micrometer; (2) the number of rows of stomata on the flat surface or surfaces; and (3) the number of stomata in two rows, each 1.68 millimeters long (the length of the micrometer scale); for binate needles the second row nearest each edge of the single flat surface was used, while for ternate needles the second row nearest the rounded surface was taken from each of the two flat surfaces. The number of rows of stomata was divided by the total flat surface width in millimeters to obtain "number of rows per millimeter of width." The number of rows per mm. of width was then multiplied by number of stomata per mm. of row to obtain number of stomata per square mm. of needle surface.

Freehand cross sections were then cut from the lower end of each of five needle segments (one per shoot) and mounted in water on microscopic slides. These were then examined under a microscope (100X) and the number of resin ducts and number of layers of hypodermal cells determined. The latter measurement proved difficult. Invariably there was a well defined, thin-walled, outer layer of cells. Inside of it occurred one or more "layers" of thick-walled cells, but these were not always in true layers, the innermost frequently containing sporadic, single cells. However, four points were systematically predesignated on each section (always between stomata) and the number of "layers" counted at each, to obtain an average for the needle.

Progeny Material

Seeds were sown on March 14-15, 1961, in a nursery at Olustee, Florida, in two nursery tests. Nursery Test 1 was designed to obtain maximum development of foliage, and for this reason seeds were sown in plastic pots 6 inches in diameter and 6 inches deep. The design was a randomized block type, with individual tree plots and five replications. From one to three seeds were sown per pot, depending upon the number available, and the seedlings were thinned to one per pot soon after germination.

Nursery Test 2 was designed mainly to produce seedlings in quantity for outplanting, which is not encompassed in this report. However, the material provided an opportunity to obtain more reliable data on seed germination and cotyledon number than could be obtained from Nursery Test 1 and hence was used for this purpose.

In Nursery Test 2, seeds of each mother tree were sown in row plots of 44 seeds each, with 3 replications. But in order to minimize competition effects, the five mother trees of each stand were randomized within stand plots, and stand plots were randomized within replications. Seeds were sown at a spacing of 1 inch within rows and rows were spaced 6 inches apart.

Germination was counted in Nursery Test 2 on March 29, 1961, and again on April 10, 1961. The first count divided by the second count, x 100, gave an index of the speed or rate of germination in per cent, while the latter count (expressed in per cent of seeds sown) alone was used as a measure of germinability. Also, cotyledon counts were obtained on up to 10 randomly chosen seedlings per row in April, 1961.

Total heights and stem diameter outside bark at ground line were measured on the seedlings of Nursery Test 1 on November 3, 1961.

In the late fall of 1961, foliar samples and measurements were obtained from the potted seedlings of Nursery Test 1 as follows: First, counts of the number of needles per fascicle were obtained on each of 10 fascicles taken from each seedling. Fascicles were chosen randomly from the upper portion of the first flush of growth. The foliar material was then handled in a manner similar to that from the parents. However, here fascicle length and fascicle sheath lengths were measured on three fascicles obtained from each seedling and the stomatal, resin duct, and hypoderm measurements were obtained for two needles per seedling.

Analyses

Single variate analyses

Statistical analyses consisted mostly of two types, single variate and multivariate. In the single variate analyses the stands were divided into three groups as follows:

Group 1. Stands within the range of the *elliottii* variety, excluding those close to the limits of the *densa* variety, as follows: Numbers 1 through 26, 31 through 40, 52, 54, and 55. Total, 39.

Group 2. Stands arbitrarily considered to be within the transition zone between the two varieties: Numbers 29, 30, 41, 42, 44, and 45. Total, 6.

Group 3. Stands within the range of South Florida slash pine as delineated by Little and Dorman (1954): Numbers 27, 28, 43, 46 through 50, and 53. Total, 9.

Note that the assignment of borderline stands in the transition zone appears inconsistent in some instances, according to limits of the varietal ranges shown in Figure 1. The reason for this is that the assignment of stands into groups was made according to the small-scale map in Little and Dorman (1954), the most recent available range map at the time. The northern limits of var. densa shown in Figure 1 were reproduced from Langdon's (1963) more recent and detailed map, revealing what appears to be inconsistencies.

The purpose of grouping the stands was to provide a means for determining the presence or absence of significant stand differences within varieties. To this extent, limitations imposed by the arbitrary nature of the grouping should be recognized.

The analyses of variance for data from parent tree samples were as follows:

Source of Variation	D.F.	Expected Mean Squares
Groups of stands (G)	2	$\sigma^2_M + k_{12}\ \sigma^2_S + k_{11}\ \sigma^2_G$
Stands within groups (S)	51	$\sigma^2_M + k_{22}\ \sigma^2_S$
Mother trees within stands (M)	209	σ^2_M
Total	262	

In the above analyses the deficiency in degrees of freedom for mother trees was due to seven "missing" trees (9D, 21D, 29E, 36B, 48A, 48B, and 48C). Tree 21D was dropped because of evidence that it was a hybrid, while the remaining missing trees were due to lack of samples.

Coefficients for the variance components for all analyses of variance were computed using the technique outlined by Gates and Shiue (1962). For the parent tree analyses the coefficients were as follows:

$k_{12} = 4.870$ $\qquad$ $k_{11} = 56.464$

$k_{22} = 4.869$

The analyses of variance for progeny data of Nursery Test 1 were as follows:

Source of Variation	D.F.	Expected Mean Squares
Replications (R)	4	
Groups of stands (G)	2	$\sigma^2_E + k_{13}\ \sigma^2_M + k_{12}\ \sigma^2_S + k_{11}\ \sigma^2_G$
Stands within groups (S)	51	$\sigma^2_E + k_{23}\ \sigma^2_M + k_{22}\ \sigma^2_S$
Mother trees within stands (M)	209	$\sigma^2_E + k_{33}\ \sigma^2_M$
Error (E)	1043	σ^2_E
Total	1309	

In the above analyses the deficiencies in degrees of freedom for mother trees and error were due to seven "missing" mother trees (21D, 22E, 29E, 42B, 42D, 48A, and 48C) and five "missing" seedlings (7A-4, 9C-4, 38D-1, 46C-4, and 46D-4). Mother tree 21D was dropped for reasons noted earlier, while the remaining missing items were due to lack of samples.

Coefficients computed for the components of variance estimates, were as follows:

$k_{13} = 4.982$ $\quad k_{12} = 23.746$ $\quad k_{11} = 277.504$

$k_{23} = 4.984$ $\quad k_{22} = 24.278$

$k_{33} = 4.980$

The analyses of variance for progeny data of Nursery Test 2 were as follows:

Source of Variation	D.F.	Expected Mean Squares
Replications (R)	2	
Groups of stands (G)	2	$\sigma^2_{E_1} + k_{12}\,\sigma^2_S + k_{11}\,\sigma^2_G$
Stands within groups (S)	51	$\sigma^2_{E_1} + k_{22}\,\sigma^2_S$
Error 1 (E_1)	106	$\sigma^2_{E_1}$
Mother trees within stands (M)	202	$\sigma^2_{E_2} + k_{33}\,\sigma^2_M$
Error 2 (E_2)	404	$\sigma^2_{E_2}$
Total	767	

In the above analyses the deficiency in degrees of freedom for mother trees was due to 14 "missing" mother trees (17D, 21D, 22E, 25D, 29A, 29C, 29E, 33C, 41B, 48A, 48B, 48C, 53A, and 53C). Mother tree 21D was dropped for reasons noted earlier while the remaining trees were dropped because of lack of samples.

Coefficients computed for the components of variance estimates for progeny data of Nursery Test 2 were as follows:

$k_{12} = 14.061$ $\qquad$ $k_{11} = 159.140$

$k_{22} = 14.223$

$k_{33} = 3.000$

The main purpose of the analyses of variance was to obtain objective estimates of the degree of variation associated with the factors studied. To aid in doing this, estimates of components of variance were obtained using the mean squares computed in the analyses of variance and the "expected mean squares" shown above (Snedecor, 1956, p. 261). The estimated components obtained in this manner were finally expressed in per cent of the total of all components (excluding the "replication" component in progeny data).

The component of variance associated with groups was considered to be expressive of the division of the species into the two varieties and the transition zone. That associated with stands within groups expresses the degree of geographic variation within varieties. These two components taken together are expressive of geographic variation for the species as a whole. If either or both of these components were statistically significant and appreciable in magnitude, isograms were drawn in an attempt to elucidate the pattern of geographic variation for the trait concerned.

Note that the above analyses assume homogeneous variances. As will later be seen, variation was frequently found to be greater in some portions of the species range than in others. This circumstance affects the validity of the estimates of variance components and the significance tests. Hence, the estimates and tests should be considered as approximations.

Multivariate analysis

Multivariate analysis was employed to examine the pattern of geographic variation considering a group of traits simultaneously. Mahalanobis' "generalized distance function" was chosen. (For discussions of this and other multivariate techniques see Rao, 1952; Howell, 1960; Wells, 1962; Wright and Bull, 1962; and Namkoong, 1963.) This function, D^2, expresses the degree of relationship between two populations, considering simultaneously the group of traits chosen. The formula for two traits (X_1 and X_2 is as follows:

$$D^2 = \frac{(\bar{X}_{11} - \bar{X}_{12})^2}{S_1{}^2} + \frac{(\bar{X}_{11} - \bar{X}_{12})\ (\bar{X}_{21} - \bar{X}_{22})}{S_{12}} + \frac{(\bar{X}_{21} - \bar{X}_{22})^2}{S_2{}^2}$$

in which $\bar{X}_{11}$ and $\bar{X}_{12}$ are the means of trait 1 for the first and second populations, respectively; $\bar{X}_{21}$ and $\bar{X}_{22}$ the means of trait 2 for the same two populations; $S_1{}^2$ and $S_2{}^2$ the pooled estimates of the variances of traits 1 and 2; and S_{12} the covariance of traits 1 and 2.

As can be seen, the magnitude of D^2 for any two populations increases with increasing difference in the means for each trait, and decreases with increasing variance and covariance within populations.

For more than two traits the formula is more conveniently expressed as follows: $D^2 = \sum_i \sum_j S_{ij}^{-1} d_i d_j$

where d_i = the mean population difference for trait i

and d_j = the mean population difference for the jth variable

and S_{ij}^{-1} = the element in the inverse of the covariance matrix corresponding to the ith and jth variable.

Using procedures outlined by Rao (1952, pp. 345 and 357), D^2 values were computed for 17 traits, including 4 from the parent tree data (cone length, cone diameter, seeds per cone, and seed weight), and 13 from progeny data (total height, stem diameter, number of ternate fascicles, needle length, sheath length, rows of stomata, stomata per mm., stomata per sq. mm., resin ducts, hypoderm thickness, germinability, speed of germination, and cotyledon number). Since there were 54 stands or "populations" a total of $\frac{(54)\ (53)}{2} = 1{,}431$ values of D^2 had to be computed. The work was done with an IBM 709 electronic computer at the University of Florida Computing Center.

RESULTS AND DISCUSSION

Results of the single variate analyses and patterns of variation for individual traits will be presented first. Following will be a recapitulation of the individual trait patterns along with a discussion of possible causes of variation. Next will be an analysis of the degree of variation (diversity) among individuals within stands and among stands within varieties and their implications. Then follows the results of the multivariate analysis, and finally a discussion of taxonomic considerations.

Single Variate Analyses

Cone dimensions

Mother tree means of cone length varied from 7.0 to 15.5 cm. (Table 3). Most of the variation was associated with mother trees within stands but stands within groups accounted for a considerable proportion (22 per cent) of it (Table 4). Since little of the variation was associated with groups of stands (6 per cent) the trait was not distinctive for varieties. The stand-to-stand variation exhibited a fairly distinctive pattern, however. Cones were relatively short in southeast Florida and increased to the north (Fig. 7). An east-west maximum occurred near the Georgia-Florida boundary (Walton County, Florida, to Duval County, Florida), above which cone length decreased slightly.

Variance components for cone diameter were rather similar to those for cone length, with stands accounting for a sizable proportion (37 per cent) and with groupings of stands accounting for none of it. Although the variation among stands was not associated with varieties, a fluctuating clinal pattern was apparent (Fig. 8). Cones were thickest

Table 3.--Means and ranges of variation for parental data

Group	Cone length	Cone diameter	Seeds per cone	Seed weight	Needles per fascicle	Needle length	Sheath length	Rows of stomata per mm. of width	Stomata per mm. of length	Stomata per sq. mm.	Resin ducts	Hypoderm layers
	Cm.	Cm.	Number	Mg.	Number	Cm.	Cm.	Number	Number	Number	Number	Number
						MEANS						
1	11.3	4.24	57.2	31.1	2.24	21.8	1.82	6.71	10.3	69.1	6.87	2.08
2	10.5	4.14	35.9	30.4	2.40	23.0	1.79	6.30	10.7	67.6	6.61	2.13
3	10.6	4.09	34.5	28.5	2.07	24.7	1.83	6.36	10.6	67.4	7.20	2.29
All groups	11.1	4.21	51.2	30.6	2.23	22.4	1.82	6.61	10.4	68.7	6.90	2.12
					RANGES AMONG CONES, NEEDLES, OR FASCICLES							
1	6.8-18.0	2.8-5.8	--	--	2-3	12-30	0.9-2.5	4.2-9.6	7.1-14.0	--	2-13	1.5-3.0
2	6.4-14.0	2.8-5.6	--	--	2-3	16-30	0.9-2.5	4.3-8.5	8.3-12.8	--	3-10	1.8-3.0
3	6.4-16.0	2.5-5.3	--	--	2-3	15-34	0.9-2.7	4.2-8.7	7.4-13.1	--	3-12	1.8-3.0
						RANGES AMONG MOTHER TREE MEANS						
1	8.2-15.5	3.1-5.3	6-127	17-48	2.0-3.0	15-27	1.2-2.3	5.3-8.5	8.3-12.4	53-94	3.0-10.2	1.8-2.4
2	7.1-12.3	2.9-5.0	3-88	19-40	2.0-3.0	19-28	1.3-2.4	5.1-7.5	9.3-12.3	55-81	4.2-9.4	1.9-2.7
3	7.0-15.1	2.7-5.0	1-80	10-51	2.0-2.4	18-31	1.1-2.3	4.8-7.6	8.7-11.9	47-76	4.4-9.4	1.9-2.9

Table 4.--Mean squares and estimates of variance components obtained from analyses of variance of parent tree data

Source of variation	Cone length	Cone diameter	Seeds per cone[a]	Seed weight	Needles per fascicle	Needle length	Sheath length	Rows of stomata per mm. of width	Stomata per mm. of length	Stomata per sq. mm.	Resin ducts	Hypoderm
MEAN SQUARES												
Groups	13.8	.50	1270**	114	0.99**	143.4**	.013	3.58**	3.12**	68	3.15	.80**
Stands/G	4.8**	.50**	180**	98**	.13**	9.2**	.139**	.32	.76**	68	1.77*	.04**
Mother trees/S	1.9	.13	41	33	.06	4.0	.024	.33	.46	48	1.20	.02
ESTIMATED COMPONENTS OF VARIANCE--PER CENT												
Groups	6	0	22	1	16	32	0[b]	15	7	0	2	37
Stands/G	22	37	32	29	14	14	49	0[b]	11	8	9	9
Mother trees/S	72	63	46	70	70	54	51	85	82	92	89	54

[a] Mean squares for seeds per cone were coded, x 0.1.

[b] This component was actually negative, but taken to be 0 here.

* Significant at the 5 per cent level.

** Significant at the 1 per cent level.

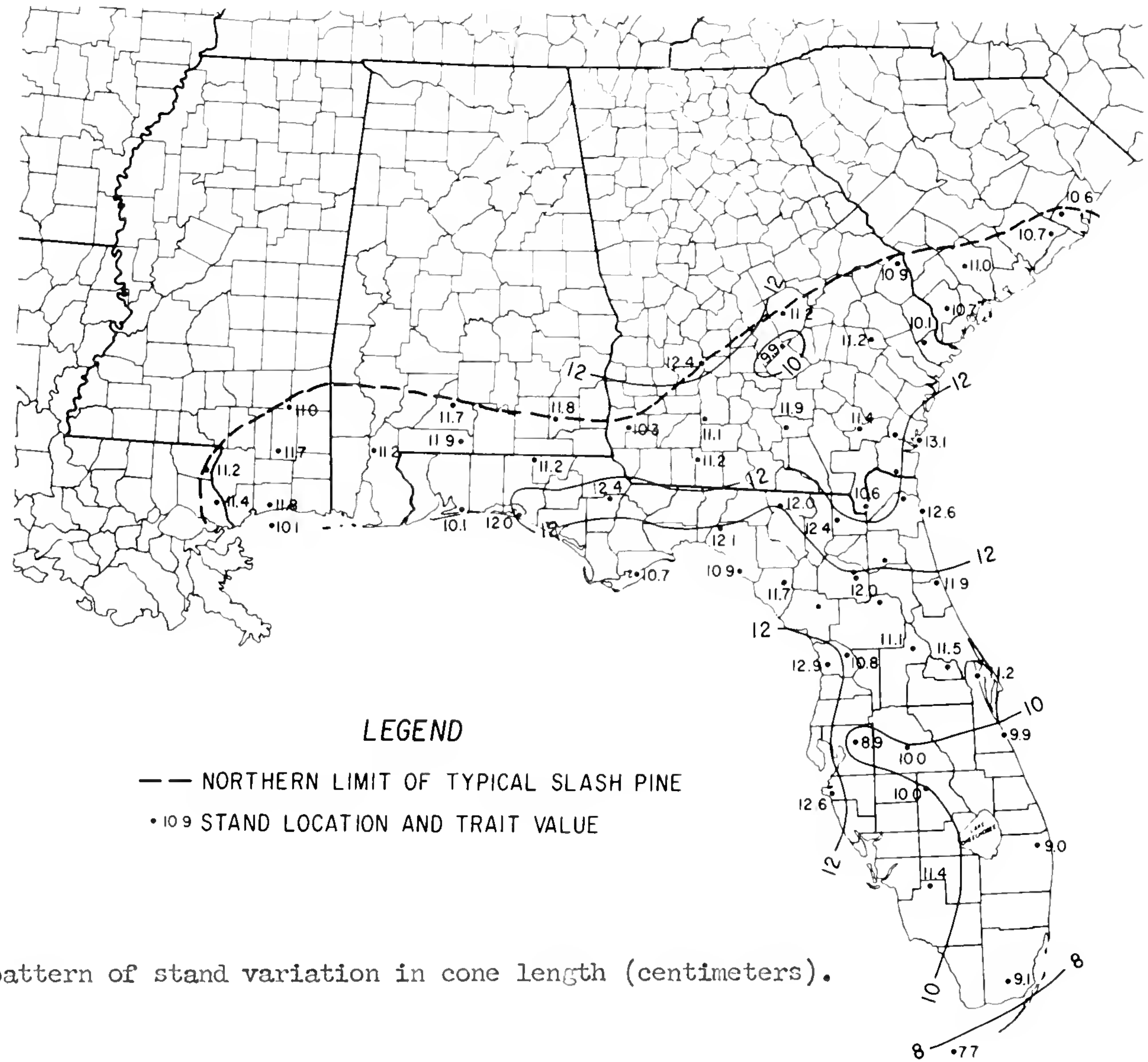


Figure 7.--The pattern of stand variation in cone length (centimeters).

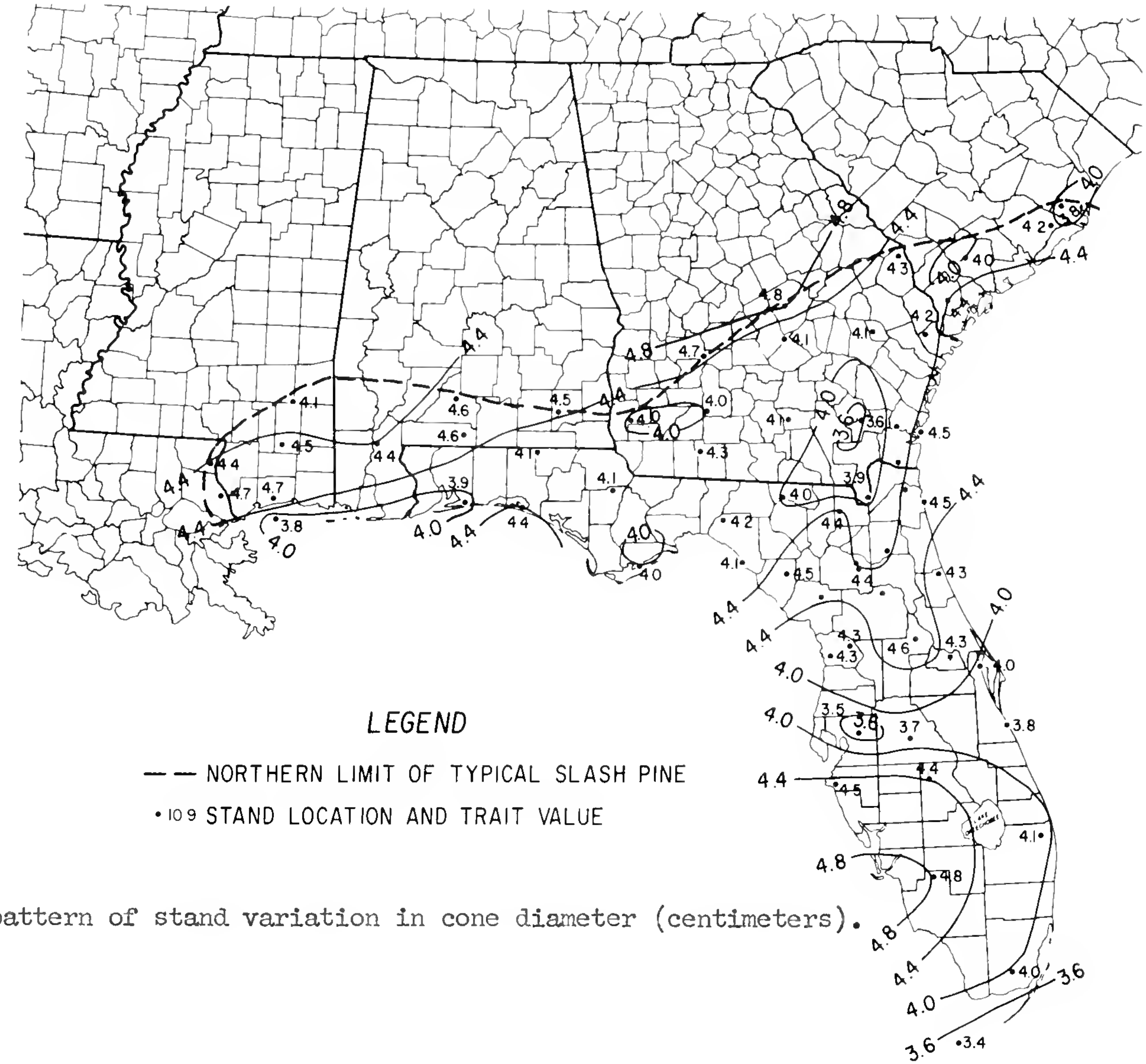


Figure 8.--The pattern of stand variation in cone diameter (centimeters).

in the collection from Collier County, Florida, and they decreased in diameter toward the north, east, and south. An east-west trough seemed to occur in the neighborhood of Polk County, Florida, and another extending southwest-northeast through the northern portion of the species range, with a minimum at Brantley County, Georgia.

The cone dimensions found here (Table 3) agree fairly well with values reported by others, as seen by the tabulation of "common" ranges below. However, it is obvious that these cone dimensions are not particularly useful for identifying varieties.

Authors	elliottii	densa	Both varieties
	Length--centimeters		
Small (1933, p. 4)	8-12	8-15	--
Coker and Totten (1937, p. 19)	--	--	6-14
Little and Dorman (1954)	9-14	7-12	--
Wakeley (1954, p. 198)	--	--	6-15
West and Arnold (1956, p. 5-6)	8-11	8-15	--
Ward (1963)	--	--	7-16
Present study (ranges among mother tree means)	8.2-15.5	7.0-15.1	7.0-15.5
	Diameter--centimeters		
Little and Dorman (1954)	4-5	3.5-5.0	--
Wakeley (1954, p. 198)	--	--	3.3-4.6
Present study (ranges among mother tree means)	3.1-5.3	2.7-5.0	2.7-5.3

Seed yield

Seed yield was extremely variable both among mother trees (1 to 127 seeds per cone) and among stands (3 to 97 seeds per cone) (Table 3 and Fig. 9). Much of the variation among mother trees was associated with groups (22 per cent) and stands within groups (32 per cent) (Table 4). Variation among stand means fell into an irregular clinal pattern (Fig. 9). Some of the irregularity may be due to differences in stand density or similar factors not studied. A high occurred in an area centering at Thomas County, Georgia, with a moderately high ridge extending to the east and west. Yield usually decreased from this ridge both to the north and south, reaching an extremely low point at Big Pine Key, Florida.

Since seed crops generally vary from year to year, and since locality by year interactions are probable (Toumey and Korstian, 1942, p. 105), one should not assume that the pattern of seed yield per cone found here would be consistent in time.

The mean sound seed yield found for the whole species, 51 seeds per cone, is lower than that reported by Wakeley (1954), 60-70 seeds per cone. The discrepancy may be due to yearly effects as noted above, or to differences in the degree of winnowing.

Seed weight

The means of seed weight for mother trees were extremely variable (10 to 51 mg. per seed) (Table 3). Much of this variation was associated with stands and it exhibited a clear, mostly clinal pattern (Table 4 and Fig. 10). A northeast-southwest trough occurred in southeast Georgia extending from Pierce County to Evans County. Seed weight increased in

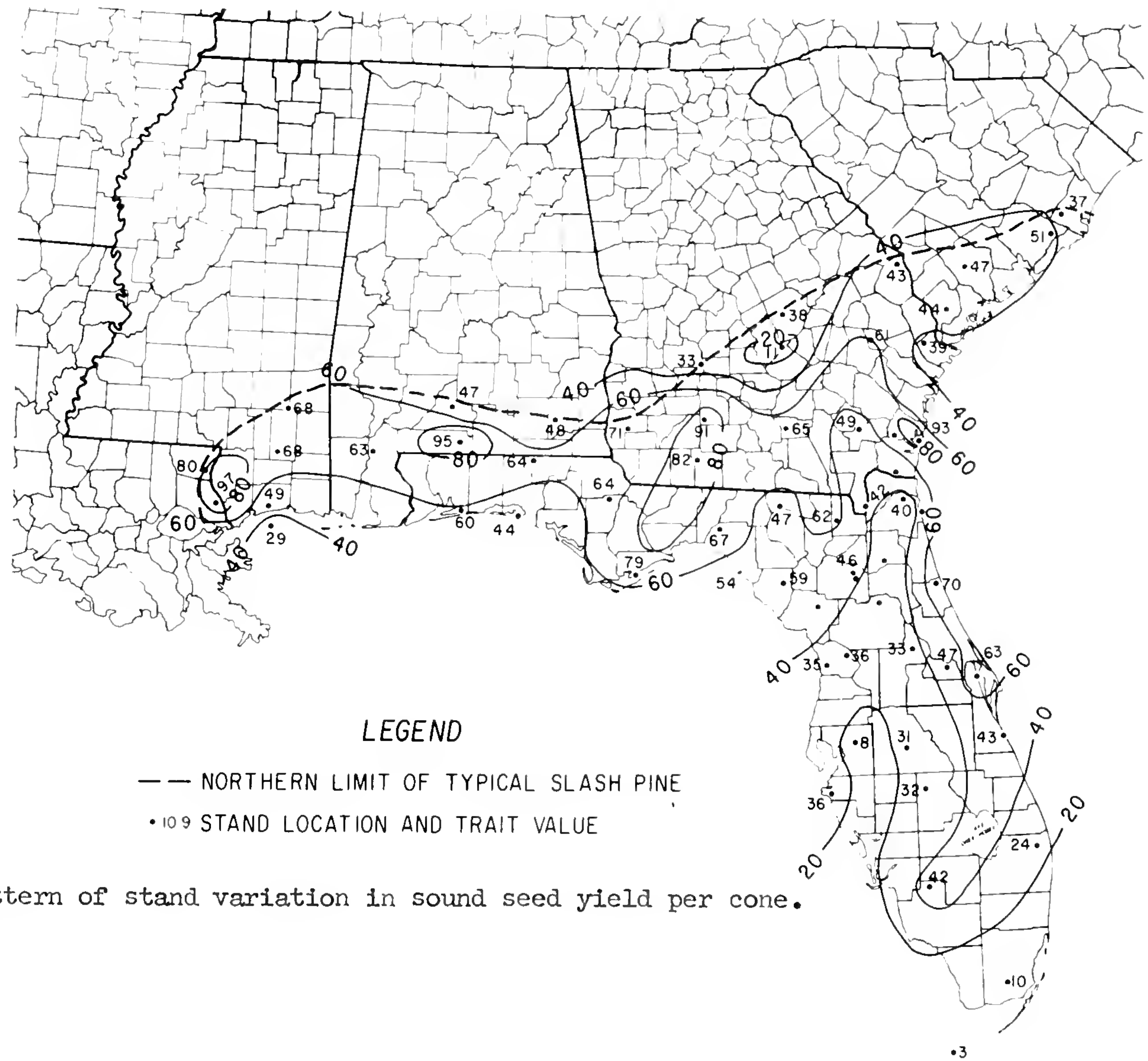


Figure 9.--The pattern of stand variation in sound seed yield per cone.

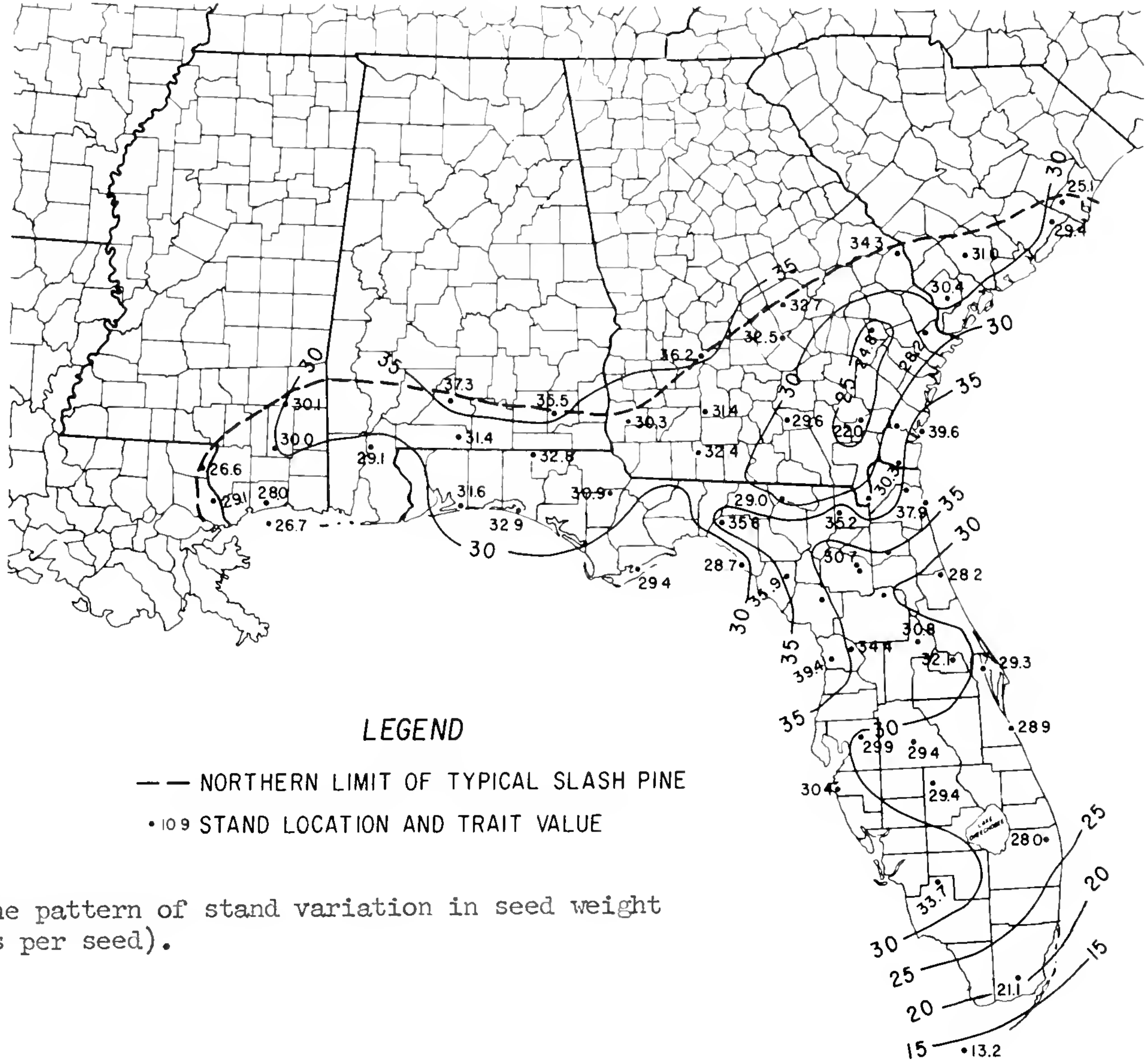


Figure 10.--The pattern of stand variation in seed weight (milligrams per seed).

all directions from this area. To the south, a northeast-southwest high occurred extending from Dixie County, Florida, to Duval County, Florida. It then decreased irregularly to the south. Note that the rate of change, however, was not uniform, the drop being the sharpest in south Florida.

The mean seed weight for all trees, 30.6 mg. (which converts to about 14,800 seeds per lb.) agrees well with the ranges for slash pine given in the Forest Service Woody Plant Seed Manual (Anonymous, 1948, p. 269), 13,000 to 16,000 seeds per lb. and also with the ranges of the means of 100-seed samples, 2.8-3.5 grams, given by Wakeley (1954, p. 198).

Germinability and speed of germination

Germinability of seed varied highly among mother trees (6 to 100 per cent) (Table 5). Significant amounts of the variation were associated with stands and groups (17 and 6 per cent, respectively) (Table 6). Germinability averaged highest in the _densa_ variety, next highest in the transition zone, and lowest in the typical variety. However, the pattern seemed to contain a large element of randomness and no isograms were drawn (Fig. 11).

The results agree with Mergen and Hoekstra's (1954), in that significant differences among seed lots from different portions of the range of the typical variety were found and that no distinctive pattern occurred. However, the differences in germinability of seed from comparable areas in the two studies showed little agreement.

Germinability of seed may of course be affected by maturity at time of collection and other factors. Although attempts were made to collect only mature cones, there is no assurance that all lots were of the same degree of maturity. Hence, even though significant stand

Table 5.--Means and ranges of variation for progeny data of Nursery Test 2

Group	Germinability[a]	Speed of germination[b]	Cotyledons
	Per cent	Per cent	Number
	MEANS		
1	60.7	67.1	7.43
2	66.7	75.3	7.29
3	73.2	89.4	6.83
All groups	63.3	71.4	7.32
	RANGES AMONG SEEDLINGS		
1	--	--	4-12
2	--	--	4-13
3	--	--	4-10
	RANGES AMONG MOTHER TREE MEANS		
1	6-96	0-99	6.0-9.4
2	23-94	7-100	6.2-9.3
3	14-100	53-100	5.5-8.0

[a] Per cent of sound seed germinating within 27 days after sowing.

[b] $\frac{\text{15-day germination}}{\text{27-day germination}} \times 100.$

Table 6.--Mean squares and estimates of variance components obtained from analyses of variance of progeny data of Nursery Test 2

	Germinability	Speed of germination	Cotyledons
	MEAN SQUARES		
Replications	5,027**	135	.199
Groups	8,271*	25,163**	17.743**
Stands/G	1,704**	1,846**	2.106**
Error 1	131	407	.087
Mother trees/S	883**	978**	.597**
Error 2	86	192	.085
	ESTIMATED COMPONENTS OF VARIANCE--PER CENT		
Groups	6	13	17
Stands/G	17	9	24
Error 1	21	37	15
Mother trees/S	43	24	29
Error 2	13	17	15

* Significant at the 5 per cent level.
** Significant at the 1 per cent level.

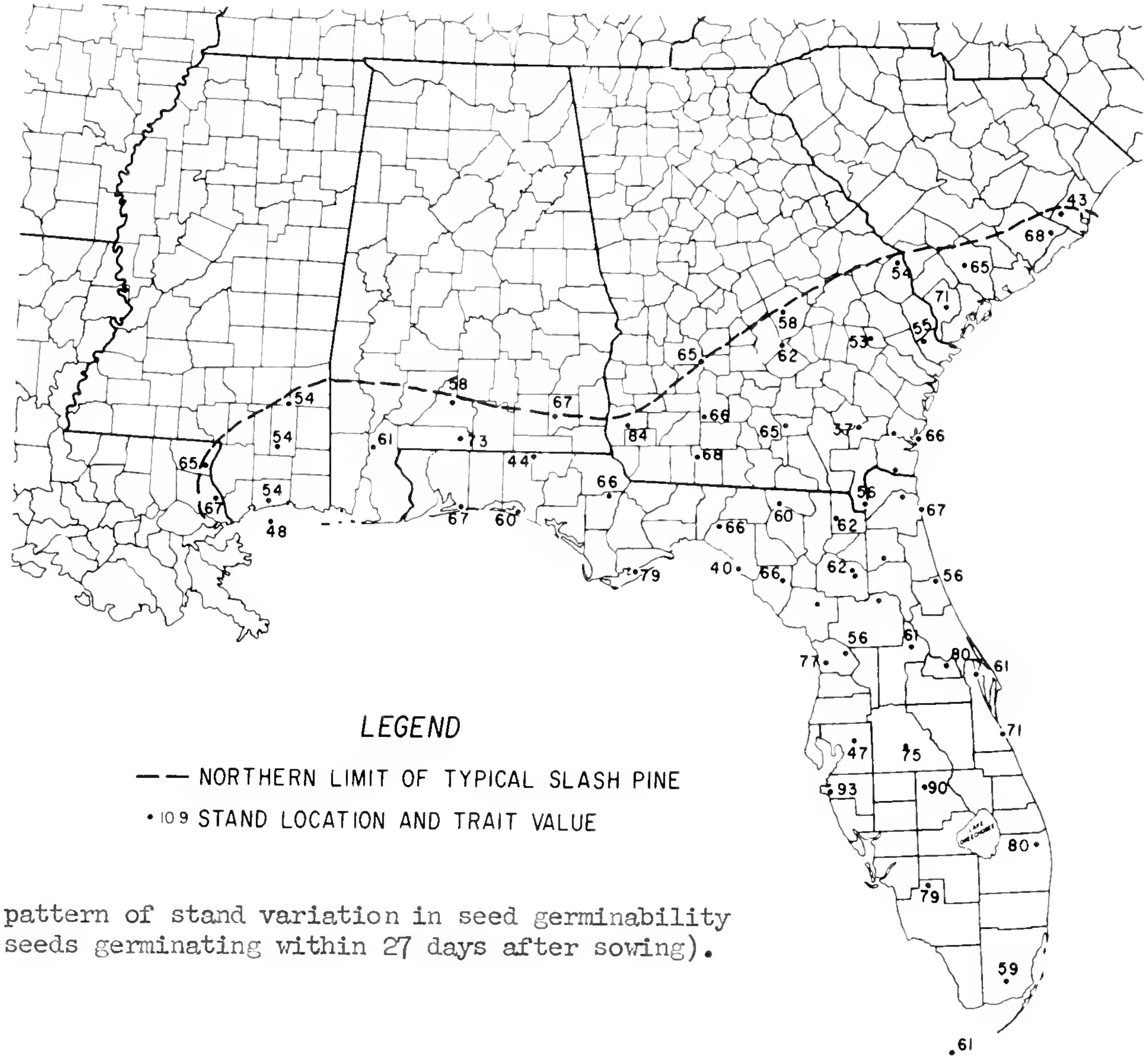


Figure 11.--The pattern of stand variation in seed germinability (per cent of seeds germinating within 27 days after sowing).

differences were found they were not necessarily genetic in nature.

Speed of germination also varied greatly among mother trees (from 0 to 100 per cent) (Table 5). Significant proportions of the variation were accounted for by groups and stands (13 and 9 per cent, respectively) (Table 6). The stand variation exhibited a distinctive clinal pattern (Fig. 12). A low occurred in Ware County, Georgia, which also tended to extend westward to Holmes County, Florida, and Catalina Island, Mississippi, and northeastward to Georgetown County, South Carolina, as well. Speed of germination increased both to the north and to the south of the trough.

Evidence of racial variation in speed of germination has also been found in lodgepole pine (P. contorta Dougl.)(Critchfield, 1957), eastern hemlock (Tsuga canadensis (L.) Carr.) (Stearns and Olson, 1958), spruce (Picea) (Schell, 1960), and ponderosa pine (Callaham, 1959 and 1962).

Like germinability, differences in maturity of seed could have had some effect upon the differences in speed of germination among stands. However, the nature and distinctiveness of the trends practically rule out the possibility that such extraneous factors could have caused the pattern. More likely it was due to genetic differences in the seeds, brought about by natural selection and causing differential response to environmental stimuli.

It is of interest to speculate on the nature of the genetic differences that were apparently present, and on the particular environmental factors to which the seeds responded at the planting site. Past studies suggest that temperature is a major environmental factor. According to Callaham (1962), the speed of germination of tree seeds is

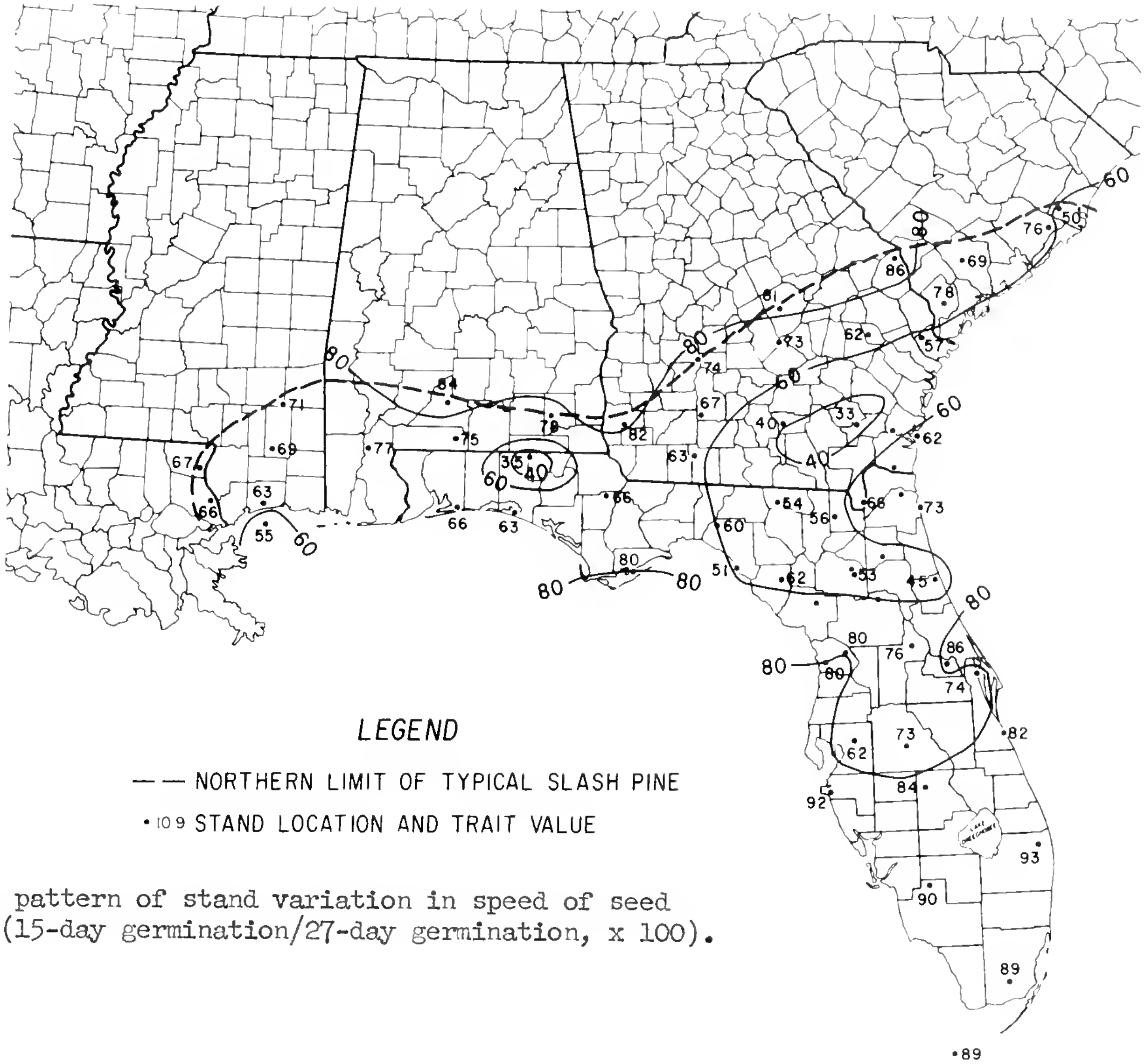


Figure 12.--The pattern of stand variation in speed of seed germination (15-day germination/27-day germination, x 100).

governed primarily by temperature, given adequate moisture and light, with germination proceeding most rapidly at some optimum temperature. Experiments by Jones (1961) suggest that photoperiod was not a predominant factor in causing the differences in rate of germination. He showed that a single exposure of slash pine seeds to 15 minutes of daylight doubled the total germination per cent over that obtained under complete darkness. But illumination periods of 8-, 12-, and 16-hours caused no differences in either speed of germination or total germination per cent.

Assuming that temperature was a major environmental factor, one might speculate that the seeds possessed different genetically-fixed optimum temperatures and this would be reflected in different rates of germination when the seeds were planted in a common environment. Such was found to be the case through laboratory tests by Callaham (1959 and 1962) for ponderosa pine. However, this alone would not explain why seeds brought north from south Florida and south from the northern limits to Olustee, Florida, germinated early.

Presence or absence of seed dormancy may have been important. In examining this possibility, it is well to review what is known about factors that may be involved. Most slash pine seed are shed in October (Cooper, 1957). Under natural conditions, seed tend to germinate in spring, but when soil moisture is adequate considerable germination may occur in early autumn (Derr, 1959). In south Florida, conditions for early fall germination would seem to occur rather frequently because October rainfall there averages about 6 inches. In contrast, October rainfall averages about 2 inches in the north. In the south, the winter months are dry (average rain about 2 inches per month) and relatively warm, while in the north they are wetter (about 4 inches per month) and considerably cooler.

Stored slash pine seeds show a mild degree of dormancy, germination being abetted by stratification, while fresh seed do not (Anonymous, 1948). These findings on dormancy were most likely based upon work with the typical variety of slash, although this point is not certain.

It is possible that dormancy may be more characteristic of northern seeds than southern seeds. In the north, if the seeds do not germinate promptly in the fall, there would likely have to be a mechanism built into the seeds to prevent germination over winter, because of the danger of cold temperatures to newly germinated seedlings. In the south, on the other hand, there would not seem to be a need for dormancy, because of the warm winters. In fact, it would seem that germination as early as possible after seed fall would carry a high selective advantage--prompt germination to avoid mortality from severe winter drouths.

The fact that northern seeds will germinate promptly under favorable conditions in the fall suggests that onset of dormancy (if it actually occurs) is delayed. Prompt fall germination undoubtedly carries a high selective advantage--trees germinating in the fall obtaining "a head start" on those germinating in the spring in regenerating denuded lands. However, prompt fall germination under suitable weather conditions plus dormancy when weather conditions fail would seem to be the best combination for the variety. These conjectures on dormancy are feasible in view of the findings with several forage species in Europe, in which it was shown that germination characteristics of species inhabiting different climates were closely tied in with dormancy mechanisms (Cooper, 1963).

Assuming both differential dormancy and different optimum temperature requirements, we might attempt to explain the results of the present study. South Florida seeds germinated earliest because they lacked dormancy. Seeds from south Georgia and north Florida germinated late because the stored seed possessed a mild degree of dormancy--had the seed been stratified differences may not have been found. Seeds from the extreme northern limits of the species range germinated promptly because, although they also may possess moderate dormancy, their optimum temperature was attained sooner, having been moved from a northerly to southerly direction. The latter conjecture assumes no difference in optimum temperature requirements within the northern region. Of course these are little more than guesses, further experimentation being necessary on this problem.

Cotyledon number

The number of cotyledons per seedling varied from as low as 4 to as high as 13 (Table 5). Much of the variation was associated with stands (24 per cent) and groups of stands (17 per cent).

Stand averages displayed a distinctive clinal pattern (Fig. 13) much like that for seed weight (Fig. 10). On the average, cotyledon numbers were higher in the north than in the south (Table 5). However, as seen in Figure 13, the pattern is much more subtle than this, with a low occurring in the north as well as in the south.

The means and ranges agree fairly well with previously reported values, as indicated in the following tabulation (means are followed by ranges in parentheses).

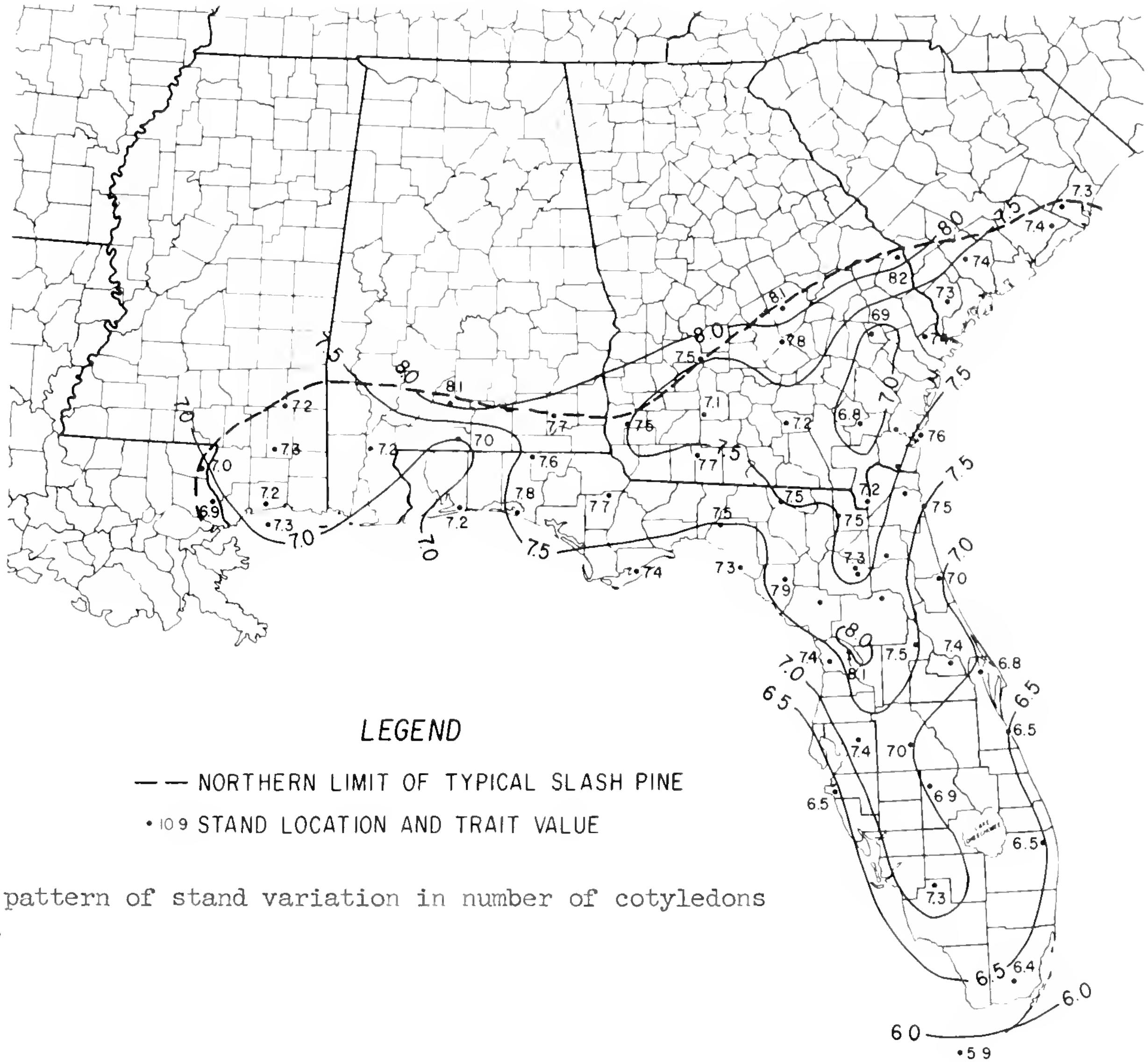


Figure 13.--The pattern of stand variation in number of cotyledons per seedling.

Author	elliottii	densa	Both varieties
	- - Numbers of cotyledons - -		
Engelmann (1880, pp. 174, 186)[a]			8(6-9)[b]
Butts and Buchholz (1940)			7.73(5-10)[b]
Little and Dorman (1954)			
DeSoto National Forest, Miss.	7.36(6-9)		
Clinch County, Ga.	7.72(5-10)		
Hendry County, Fla.		6.76(5-8)	
Present study (ranges are among seedlings)	7.43(4-12)	6.83(4-10)	7.32(4-13)

a Cited by Little and Dorman (1954)

b Origin not specified

The correlation between cotyledon number and seed weight on a stand mean basis was .72, highly significant; the pooled correlation for mother trees within stands was .42, also highly significant.

Racial variation in respect to cotyledon number has also been found in loblolly pine (Thorbjornsen,1961). The positive correlation between seed weight and cotyledon number agrees with findings by Buchholz (1946) for ponderosa pine.

Total height

One-year-old seedling heights varied greatly and the majority of the variation (66 per cent) was associated with groupings of the stands. Seedlings in the northern portion of the species range were tallest (Tables 7 and 8, and Figs. 14 and 15). Variation in the north was relatively small but heights decreased rapidly going from north to south through Florida. Thus, the pattern is largely random in the north and clinal through Florida. There was also a modest east-west gradient

Table 7.--Means and ranges of variation for progeny data of Nursery Test 1

Group	Total height	Stem diameter	Needles per fascicle	Needle length	Sheath length	Rows of stomata per mm. of width	Stomata per mm. of length	Stomata per sq. mm.	Resin ducts	Hypoderm layers
	Cm.	Mm.	Number	Cm.	Cm.	Number	Number	Number	Number	Number
					MEANS					
1.	26.7	7.1	2.88	15.1	0.80	5.88	9.0	53.0	2.42	1.52
2	21.6	7.4	2.85	17.2	.81	5.71	8.6	49.2	2.33	1.44
3	12.8	8.5	2.64	18.2	.76	5.64	8.7	48.8	2.33	1.38
All groups	23.9	7.4	2.84	15.8	.79	5.83	8.9	51.9	2.40	1.49
				RANGES AMONG NEEDLES OR FASCICLES						
1	--	--	2-5[a]	8-23	0.3-1.5	3.5-9.4	5.9-12.8	--	0-5	1-2
2	--	--	2-4[a]	10-29	0.5-1.3	4.0-8.3	5.6-11.9	--	2-4	1-2
3	--	--	2-4[a]	10-28	0.5-1.4	3.3-8.9	5.0-13.1	--	2-5	1-2
				RANGES AMONG SEEDLINGS OR SEEDLING MEANS[b]						
1	10-54	3-13	2.1-3.0	8-22	0.4-1.3	3.7-8.4	6.4-11.9	32-84	0.0-5.0	1-2
2	9-39	2-12	2.2-3.0	10-26	0.6-1.1	4.1-7.8	6.0-11.2	31-68	2.0-3.5	1-2
3	5-40	3-15	2.0-3.0	11-26	0.5-1.3	3.7-8.7	5.2-11.0	32-77	2.0-4.5	1-2
				RANGES AMONG MOTHER-TREE MEANS						
1	18-35	5-9	2.6-3.0	12-19	0.6-1.1	4.6-7.0	8.0-10.0	38-65	1.8-3.0	1.1-1.9
2	12-30	6-9	2.6-3.0	15.21	0.7-0.9	4.9-6.4	8.0-9.5	40-58	2.1-2.8	1.3-1.6
3	8-27	6-11	2.2-2.9	14-21	0.6-1.0	4.9-6.7	7.6-9.7	43-60	2.0-3.2	1.2-1.6

[a] Four- and 5-needled fascicles were extremely rare.

[b] Ranges are among seedlings for total height and stem diameter, and among seedling means for all other traits.

Table 8.--Mean squares and estimates of variance components obtained from analyses of variance of progeny data of Nursery Test 1

Source of variation	Total height	Stem diameter	Needles per fascicle	Needle length	Sheath length	Rows of stomata per mm. of width	Rows of stomata per mm. of length	Stomata per sq. mm.	Resin ducts	Hypoderm layers
					MEAN SQUARES					
Replications	1,340**	45.3**	0.16**	163.0**	0.146**	2.86**	0.50	307**	0.72**	0.22**
Groups	17,224**	168.3**	5.13**	980.6**	.147	6.10**	17.57**	2,096**	1.09	1.71**
Stands/G	156**	5.7**	.11**	17.0**	.086**	1.14*	1.18**	136**	.35	.21**
Mother trees/S	39**	2.5**	.05**	5.6**	.027**	.74**	.72*	73**	.30**	.09**
Error	23	1.4	.03	3.6	.018	.42	.59	47	.18	.06
					ESTIMATED COMPONENTS OF VARIANCE--PER CENT					
Groups	66	25	32	44	1	3	8	11	1	7
Stands/G	5	6	5	6	11	3	3	4	1	7
Mother trees/S	4	8	4	5	8	12	4	8	11	10
Error	25	61	59	45	80	82	85	77	87	76

* Significant at the 5 per cent level.
** Significant at the 1 per cent level.

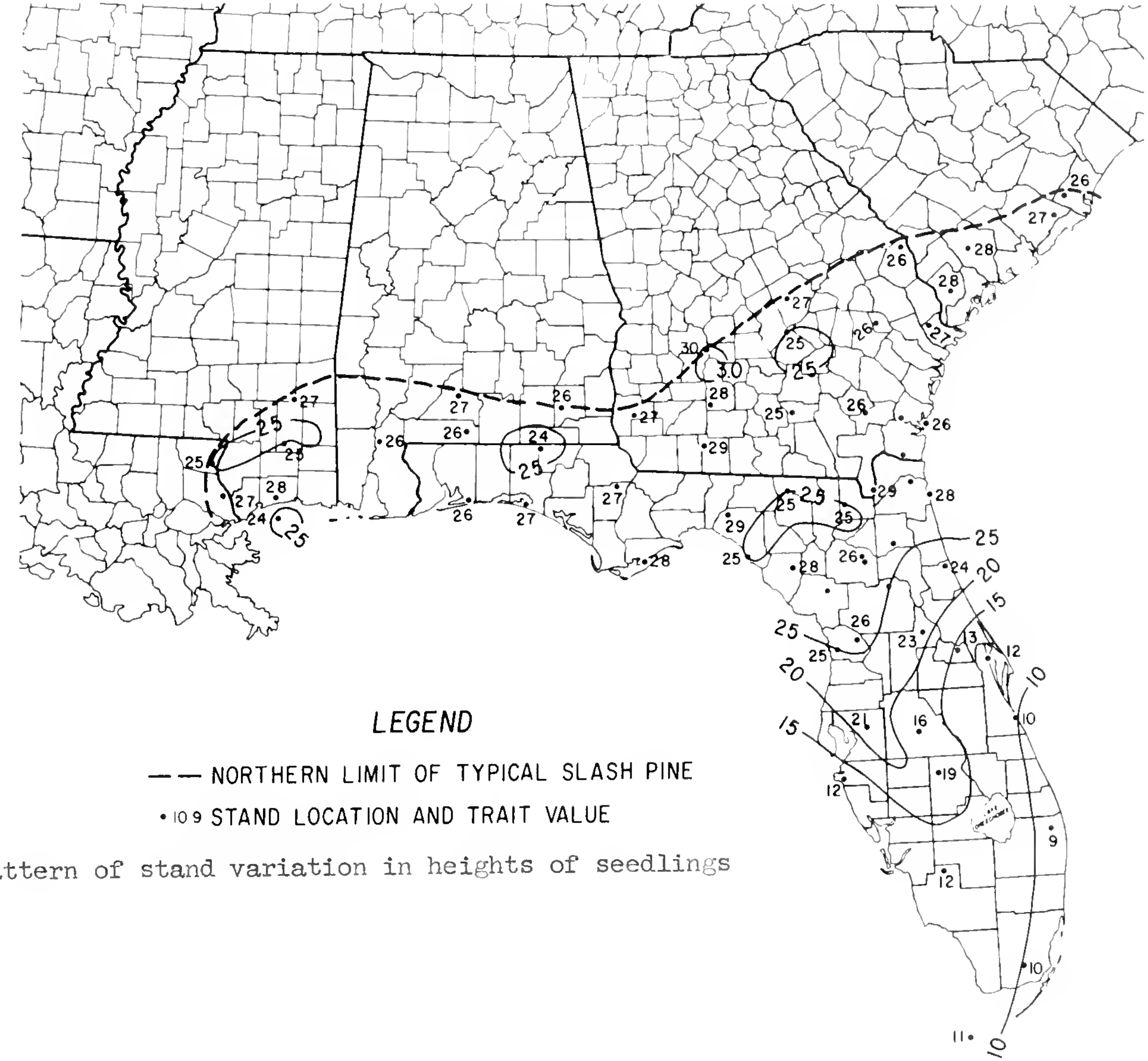


Figure 14.--The pattern of stand variation in heights of seedlings (centimeters).

Figure 15.--One-year-old slash pine seedlings, showing differences in total height and stem diameter. Upper photo represents a latitudinal transect through the species range, the one on the extreme left being from Big Pine Key, Florida, and the one on the extreme right from Sumter County, Georgia. Lower photo shows differences between trees from the west coast (the two trees on left), the interior (center two), and the east coast (the two on right) of central Florida.


53B5
46C2
28D3
23D5
27A4
26A5
18D1
19D5
20A5
21D5


28-B-3
28-C-4
45-C-5
44-E-2
50-E-1
49-B-1

through central Florida, seedlings being tallest in the center of the state, and shortest along the coasts.

In a general way these results are in harmony with Little and Dorman's (1954) use of stem height as a diagnostic feature for identifying varieties. However, because of the gradient in Florida it apparently would be difficult to classify seedlings in the transition zone.

The fact that seedlings in the north-central region were not particularly taller than those at the extremities of the north, seems to disagree with findings by Squillace and Kraus (1959). However, seeds were relatively small and germination relatively late in the north-central region. These two factors apparently had some effect upon heights. The within-stand pooled correlation coefficient between seedling height and seed weight was .31 (significant at the 1 per cent level) and between seedling height and rate of germination, .17 (significant at the 5 per cent level).

On the other hand, the superiority in early height growth of trees from the north to those of the south is great enough to be real in spite of seed weight and rate of germination effects. Reasons for this difference probably lie in the fact that the south generally suffers from extremes of climatic and other environmental conditions more so than does the north. Such factors could include poor rainfall distribution with frequent droughts in spring and flooding in summer, damaging tropical storms, and possibly frequency of fires. In the south, natural selection is probably relatively strong for resistance to these factors, which may cause relatively weaker selection for rapid growth than in the north.

Admittedly there are also climatic extremes in the peripheral portions of the north. For example, relatively cold temperatures and frequent ice storms are characteristic of the area just south of the northern limits; tropical storms are relatively frequent along the Gulf coast; rainfall distribution is relatively unfavorable along the coasts of Georgia and South Carolina; conditions conducive to fusiform rust damage seem to be most favorable at the northern extremities (McCulley, 1950).

The east-west gradient through much of Florida may be associated with the difference between mean maximum and mean minimum daily temperatures (Fig. 3)--trees tend to be tall where the temperature difference is relatively high. This possible association is supported by findings reported by Kramer (1957) and Hellmers (1962)--in laboratory tests loblolly pine and northern red oak (Quercus rubra L.) grew fastest under the greatest day-night temperature differential tested.

Stem diameter

Variation in stem diameter showed a moderately high racial component (25 per cent for groups and 6 per cent for stands within groups) and the stand means exhibited a clinal pattern (Table 8 and Fig. 16). Stems were thickest in the South Florida seedlings and they decreased rather uniformly to a northeast-southwest low extending from Taylor County, Florida, to Liberty County, Georgia. North of this trough, diameters increased slightly, but were not as large as those from south Florida. Stems usually were thicker (especially relative to height) along the coasts of Florida than in the interior.

Thick stems are an indication of a carrot-like taproot. Thus, in a general way, the results agree with Little and Dorman's (1954) use of

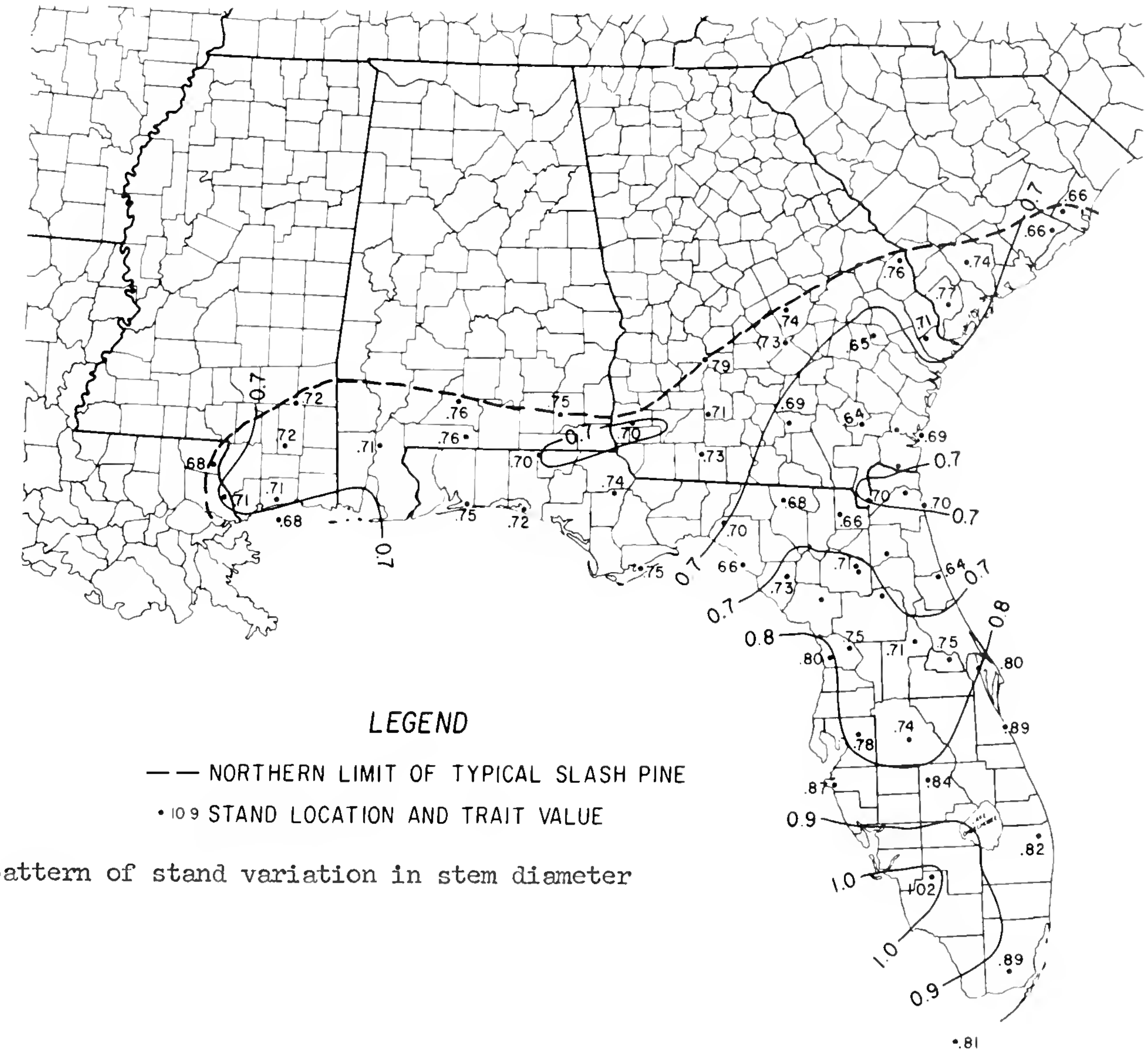


Figure 16.--The pattern of stand variation in stem diameter (centimeters).

this trait as a diagnostic feature. Stands in groups 1, 2, and 3, averaged 7.1, 7.4, and 8.5 cm., respectively. Trees from stands near the northern limits of the species range had moderately thick stems but they were taller than South Florida seedlings and hence would not detract from diagnostic utility of this trait. However, like total height, the difficulty is that because of the clinal nature of the pattern it would apparently be difficult to classify trees or stands in the transition zone.

Thickness of stem in slash pine seedlings has undoubtedly been important in natural selection. South Florida seedlings, which characteristically have thick stems, are more resistant to fires than north Florida seedlings (Ketcham and Bethune, 1963). Apparently, this thickening of the hypocotyl, which is mostly dead outer bark but also inner bark and wood, imparts a degree of insulation against heat (Little and Dorman, 1954). The thick stem also probably provides a means for storing food, utilizable for sprouting when the crown burns. Hence, the trait is assumed to have resulted as an adaptive response to fire (Little and Dorman, 1954).

If the trait is an adaptive response to fire, one would expect that the frequency of natural fires, or the extent of damage from fires, increases gradually from north to south, following the pattern of variation in stem thickness. No concrete and reliable data could be found to check this possibility. However, as noted earlier, slash pines in the north were originally restricted to ponds, pond margins, and other wet areas. Hence, it is possible that fires in the south invaded slash pine stands more frequently, and perhaps were more intense, than in the north. Extended

late winter and early spring drouths and high winter temperatures, common in the south, may be factors affecting the frequency and intensity of fires.

Regressions were calculated to determine factors that might have been involved in the apparent natural selection on stem diameter. Stem diameter (stand means in centimeters, Fig. 16) was used as the dependent variable. Independent variables used were as follows: (1) latitude (stand values in degrees); (2) the sum of precipitation-evaporation (P-E) ratios for months of February through April (stand values, Fig. 6); and (3) mean January temperature (stand values in °F., Fig. 2). P-E ratios (used as a measure of late winter-early spring drouth) and January temperature were considered as possible environmental factors causing natural selection. Latitude in itself could not, of course, cause natural selection, but the variable was included to test the apparently strong latitudinal trend and to see if effects of P-E ratios and temperature, independent of latitude, could be shown. The analyses included simple, multiple, and curvilinear regressions. Results are shown below.

Simple Regression Analyses

Stem diameter (Y) on:	Regression coefficients	Coefficients of determination
		Per cent
Latitude (X_1)	-.0232	40.1**
Feb.-Apr. P-E ratios (X_2)	-.0042	15.6**
Jan. temperature (X_3)	.0090	36.7**

Multiple and Curvilinear Analyses

Stem diameter (Y) on:	Standard partial regression coefficients	Coefficients of determination
		Per cent
X_1 and X_2	-.615, -.031	40.2**
X_1 and X_3	-.702, -.072	40.1**
X_1, X_2, and X_3	-1.111, -.205, -.621	40.8**
X_1 and X_1^2	-6.649, 6.000	48.1**
X_3 and X_3^2	-2.765, 3.385	46.8**

** Significant at the 1 per cent level

In the simple regression analyses latitude showed the strongest relationship to stem diameter, as indicated by the coefficients of determination. This suggests that some environmental factor, correlated with latitude, was instrumental in causing the stem diameter pattern. The regression coefficient for temperature was almost as strong as latitude, while that for P-E ratios was considerably weaker, but still highly significant. Multiple regressions showed no significant increase in the variance accounted for (indicated by the coefficients of determination) over and above that accounted for by latitude alone. This was due to high intercorrelations between the independent variables. Therefore, there is no proof that either temperature or P-E ratios had effects independent of latitude. Because of the reversal in trend of stem diameter in the north-central area, curvilinear regressions were tried for latitude and temperature. Both regressions accounted for significantly (1 per cent level) more of the variance above that accounted for by respective linear regressions. However, latitude still was superior to temperature.

From the analysis we can only conclude that the latitudinal trend in stem diameter, with a reversal in the north-central area, was significant. Temperature and P-E ratio may have had some real association with the trend, but some other environmental factor must also be involved.

<u>Needles per fascicle</u>

Both binate and ternate fascicles were found in the parental samples, but the relative frequencies varied considerably as indicated by average numbers of needles per fascicle (Table 3). Stand differences displayed a very distinctive pattern, with a north-south high in extreme southeast Georgia and northeast Florida, and another northwest-southeast high in north-central Florida (Fig. 17). Needles per fascicle usually decreased gradually away from these highs. A notable feature was that, although numbers were low in south Florida, they were also usually low at the extremities of the species range. Thus, the results do not agree well with Little and Dorman's (1954) recommended use of this character for separating varieties--differences in sampling technique may have caused the disagreement. Average number of needles per fascicle in the progenies was generally higher than in the parents (Table 7). This may be due to an effect of tree age, or to the fact that the progenies, being grown in a nursery, had a more favorable environment than trees under natural conditions. A very few progeny fascicles contained four needles and one contained five.

The pattern of variation among stands in the progenies was somewhat similar to that in the parents (Fig. 18). However, the two pronounced highs found in the parents were less noticeable in the progenies and also the difference between south Florida and the remainder of the species range was more pronounced in the progenies.

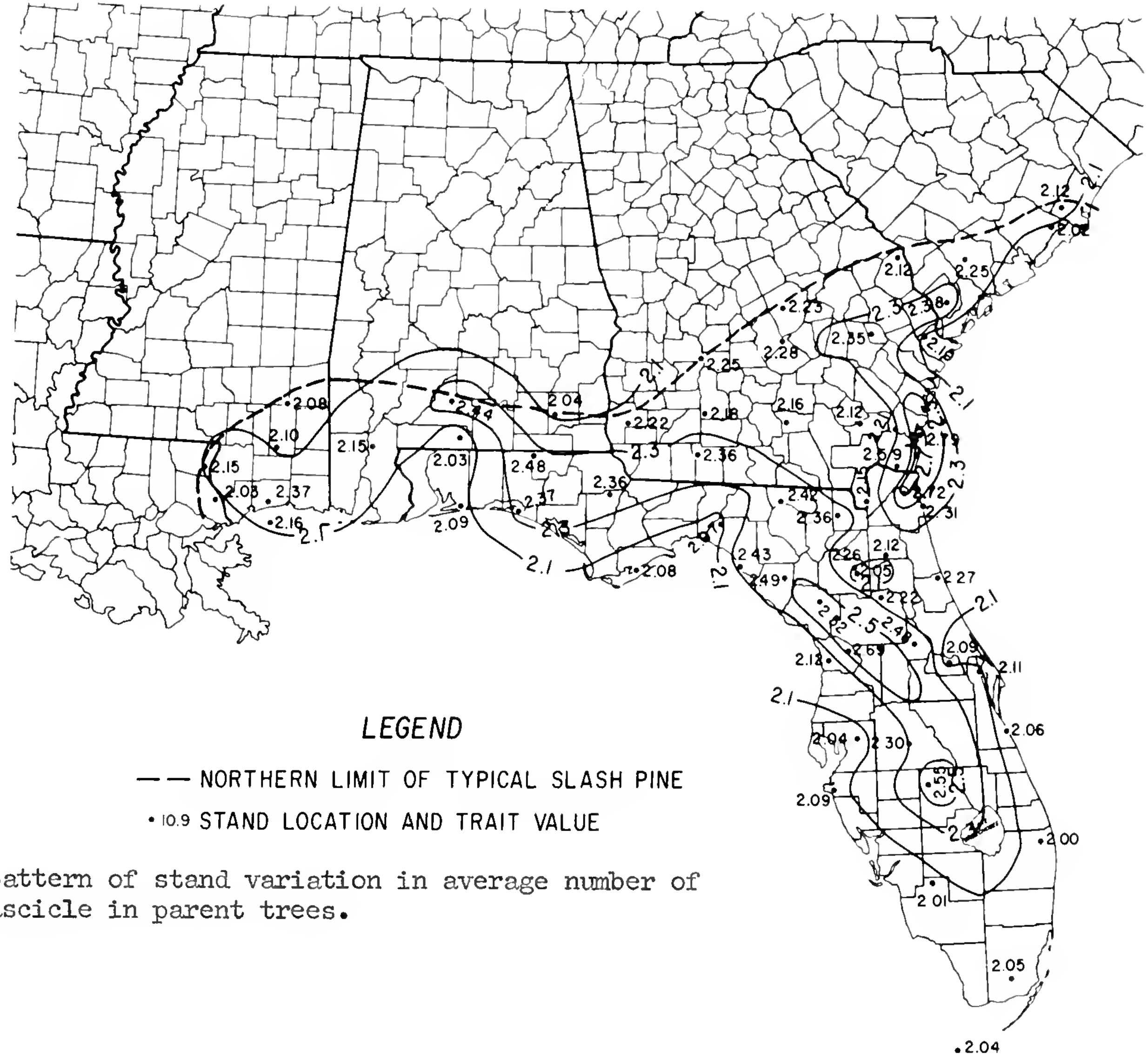


Figure 17.--The pattern of stand variation in average number of needles per fascicle in parent trees.

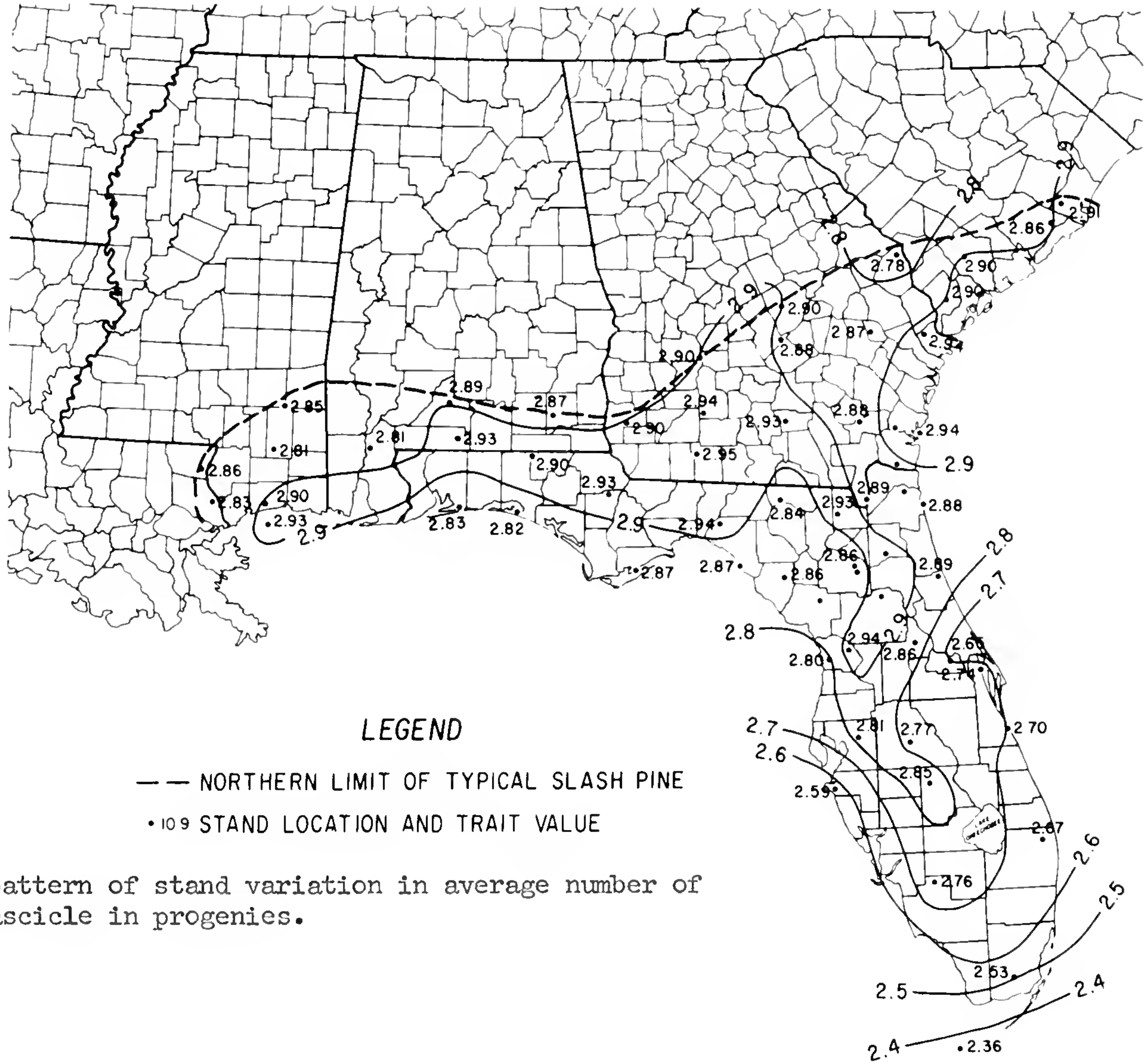


Figure 18.--The pattern of stand variation in average number of needles per fascicle in progenies.

The pattern of variation in both parents and progenies seems to be, in some respects, associated with severity of environment. The low in south Florida coincides with unfavorable distribution of rainfall and the low in the extreme north is associated with cold winter temperatures. Somewhat similar trends have been reported for ponderosa pine. Needles per fascicle in ponderosa pine tend to be low in eastern portions of the species range (Weidman, 1939; Haller, 1962; and Wells, 1962), where the climate is relatively severe and the trees are generally slower growing. The results agree with Shaw's (1914) statement that in some species of trees the number of needles per fascicle is dependent upon climatic conditions, smaller numbers occurring in colder regions.

The apparent relation of needles per fascicle and severity of climate may be associated with photosynthetic efficiency. It can be shown that a ternate fascicle has about 20 per cent more leaf surface area per unit of needle volume than a binate fascicle of the same diameter and length. Thus, a ternate fascicle, having more surface area for absorption of light and for exchange of gases per unit of chlorophyll-bearing tissue, may be more efficient photosynthetically than a binate one. A binate type, on the other hand, would seem to be an adaptation for conserving moisture loss or for frost hardiness, at the expense of growth efficiency. High frequency of ternate fascicles then may be an adaptation to vigorous growth in optimum climate while a tendency toward a preponderance of binate ones an adaptation to less favorable climate. These possibilities would seem to be worthy of further study.

Needle length

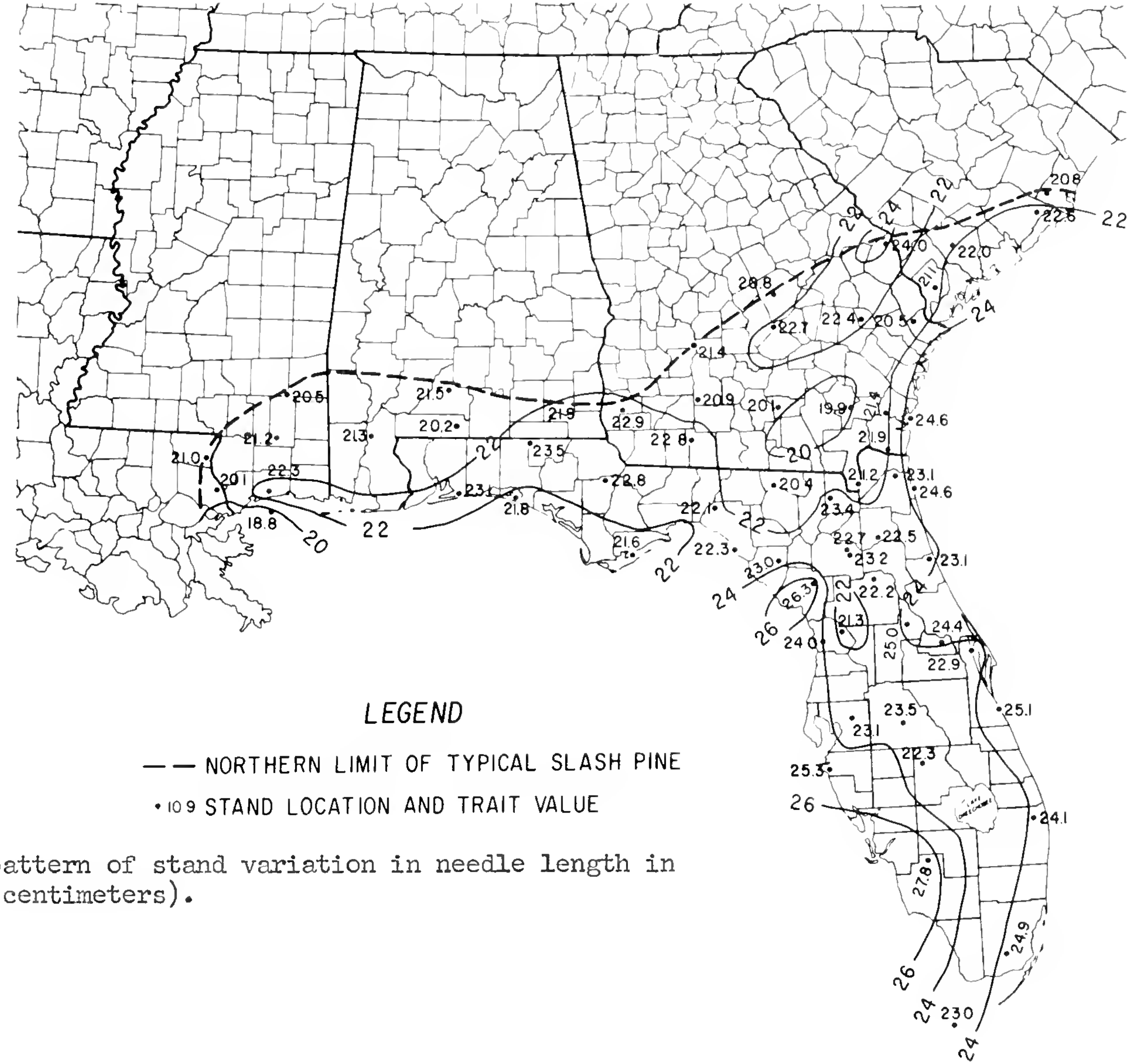
Needle length in the parent trees exhibited a rather complicated pattern of variation among stands (Fig. 19). In general, needles averaged longer within the range of variety densa than in the north (Table 3). However, the tendency was not uniform, highs occurring in the north as well as in the south. Needles tended to be relatively long in the coastal areas, suggesting a possible tie-in with the difference between mean minimum-mean maximum temperatures (Fig. 3). But the correlation coefficient between these two variables was nonsignificant ($r = -.23$).

The pattern in the progenies was simpler, containing a strong element of clinal variation (Fig. 20). Needles were generally long in south Florida (excepting at the extreme tip) and they decreased northward to a northeast-southwest low through south Georgia, and then increased above this area. The pattern vaguely resembles that in the parents in that needles were, on the average, longest in the south (Table 7).

The ranges in lengths of needles for parent material are compared against those shown by others below.

Author	elliottii	densa	Both varieties
	- - Centimeters - -		
Harlow (1931)			15-30
Small (1933, p. 4)		18-30	
Coker and Totten (1937, p. 19)			15-23[a]
West and Arnold (1956, p. 5-6)	18-30	18-30	
Present study (ranges among mother tree means)	15-27	18-31	15-31

a Rarely, 10-25



LEGEND

— — NORTHERN LIMIT OF TYPICAL SLASH PINE

• 10.9 STAND LOCATION AND TRAIT VALUE

Figure 19.--The pattern of stand variation in needle length in parent trees (centimeters).

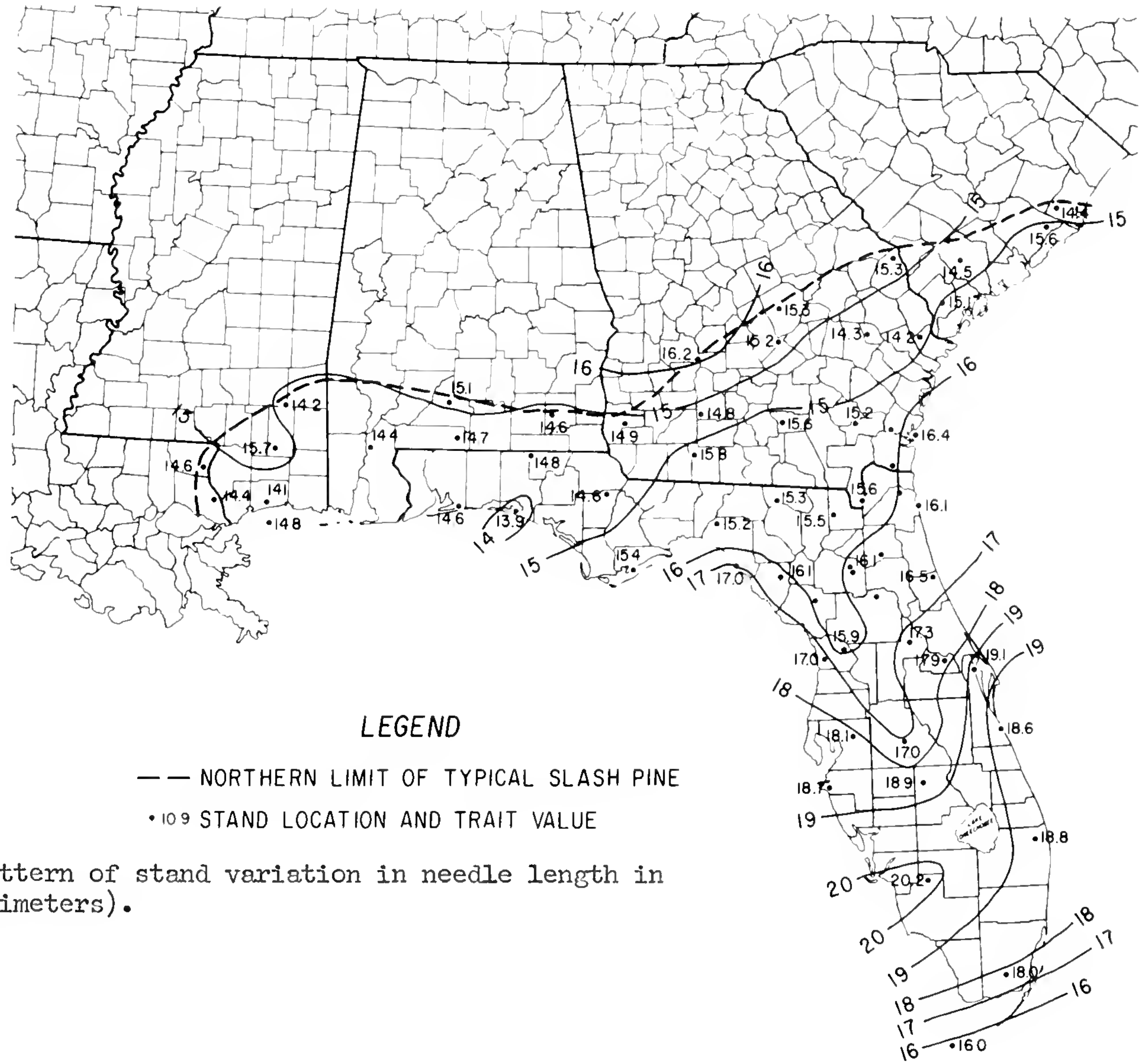


Figure 20.--The pattern of stand variation in needle length in progenies (centimeters).

Fascicle sheath length

Variation in fascicle sheath length in the parental data was strongly associated with stands, none of it being associated with groups (Table 4). But the pattern of stand variation was rather intricate (Fig. 21). A significant feature was that a pronounced north-south low occurred through the center of Florida and southeast Georgia.

In the progenies the stand component of variation was significant but rather small, 11 per cent (Table 8). Stand means displayed no particular trends, with a large element of randomness (Fig. 22).

The ranges of variation in sheath length found in the parental data do not agree very well with reports by others as seen below. The discrepancies may be due to differences in maturity of the foliage sampled, or to differences in technique of measurement (such as inclusion or exclusion of frayed ends).

Authors	elliottii	densa
	- - Centimeters - -	
De Vall (1941a)	0.8-1.3	1.0-1.4
West and Arnold (1956, p. 5-6)	1.3 and under	1.6
Present study (ranges are among mother tree means)	1.2-2.3	1.1-2.3

De Vall (1940) considered fascicle sheath length to be very diagnostic, it being unaffected by climate, soil type, tree age, etc., and that the character was useful to separate slash and longleaf pine.

Stomatal measurements

Results of the three measures of stomatal frequency were similar in that (1) in the parental data only small amounts of variance were associated

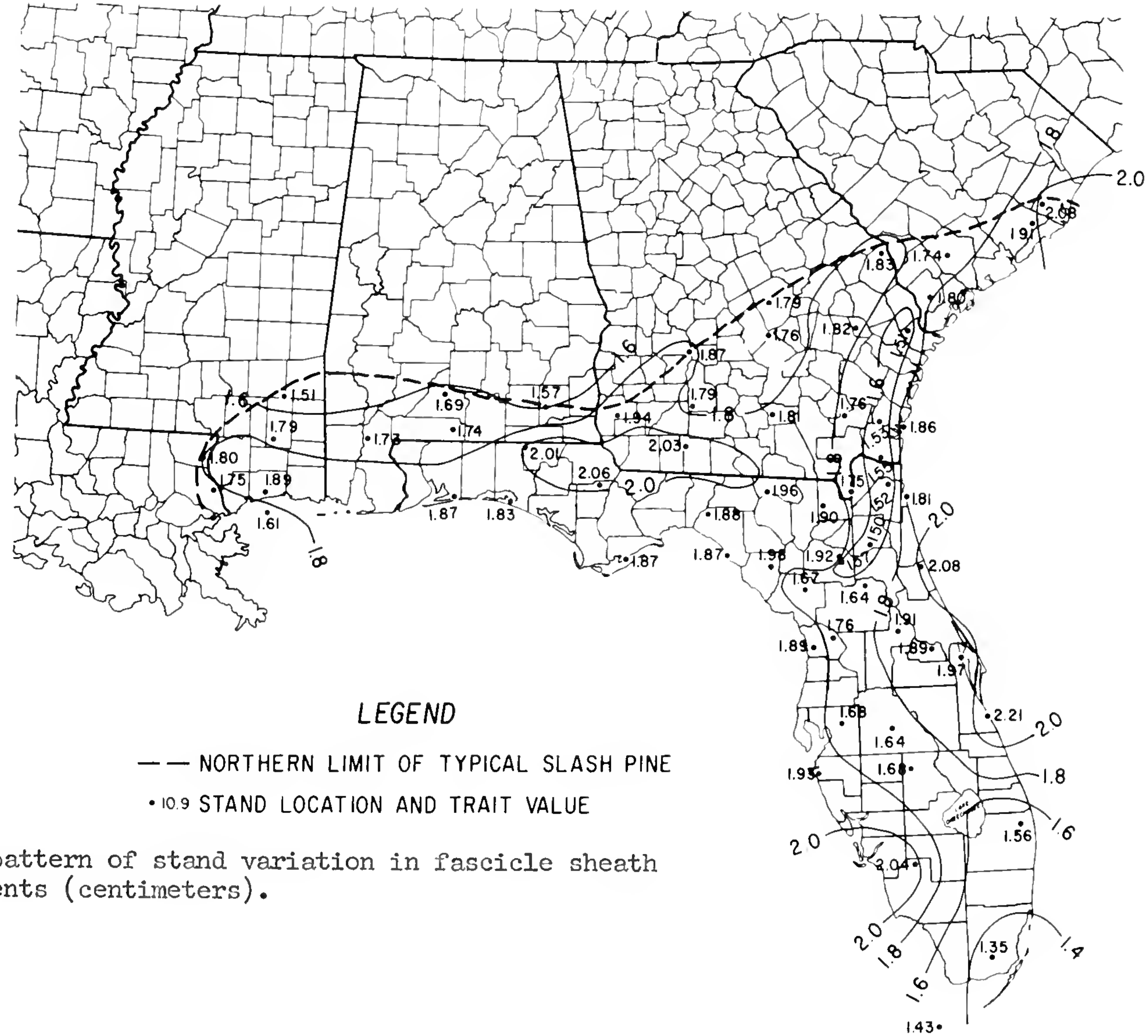


Figure 21.--The pattern of stand variation in fascicle sheath length in parents (centimeters).

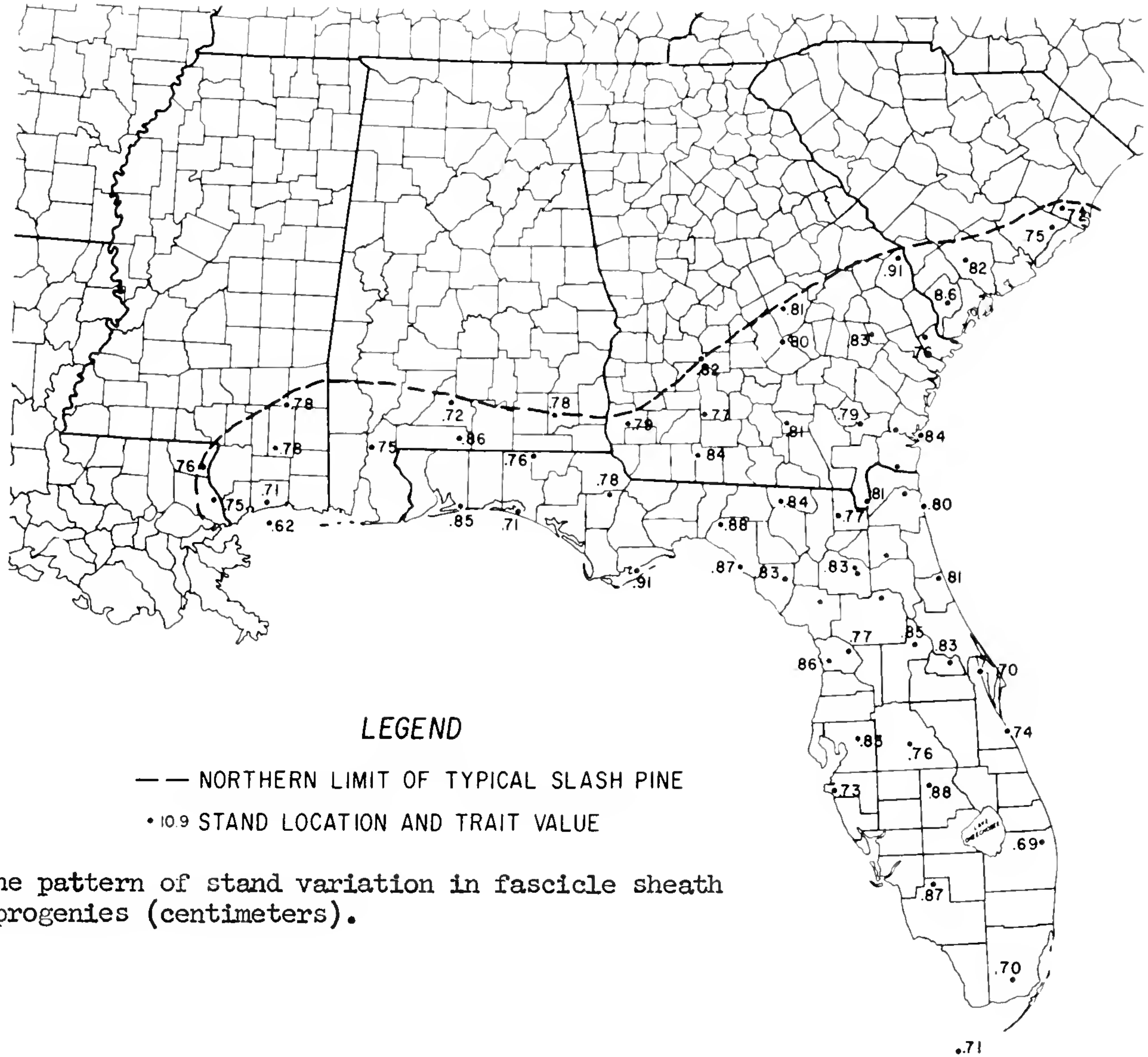


Figure 22.--The pattern of stand variation in fascicle sheath length in progenies (centimeters).

with groups or stands, with the patterns of the stand means being largely random; and (2) in the progenies it was possible to show patterns for the stand means, although they were somewhat erratic (Figs. 23 through 28). A common feature was a tendency for stomatal frequency (all three types of measurements) to average relatively high in the north and low in the south, and also some tendency for a high to occur in the north-central area.

Mergen (1958) found a clinal pattern for stomata per mm. increasing from west to east in slash pine progenies from 12 sources encompassing much of the northern part of the species range in Georgia and Florida. The pattern was curvilinear, however, with most of the variation occurring in the east. His pattern is only vaguely apparent in the progeny data of the present study--a high occurred in east Georgia but another high occurred in the extreme western portion of the species range.

Thorbjornsen (1961) found geographic variation in stomata per mm. in natural stands of loblolly pine. His pattern was somewhat similar to Mergen's, frequency tending to be highest in the eastern part of the range. But the trend was not uniform, the pattern appearing to be somewhat random east of the Mississippi river. He also found a rather strong positive correlation of stomata per mm. with a drought index, the ratio of May-August precipitation over average summer temperature. A check for a similar relationship was sought in the present data for slash pine, with no success--if anything there was a slight negative trend. Apparently the relationship Thorbjornsen found was mainly due to the very low summer rainfall west of the Mississippi being coincident with low stomatal frequency in that area. If so, the lack of a relationship for slash pine is not surprising.

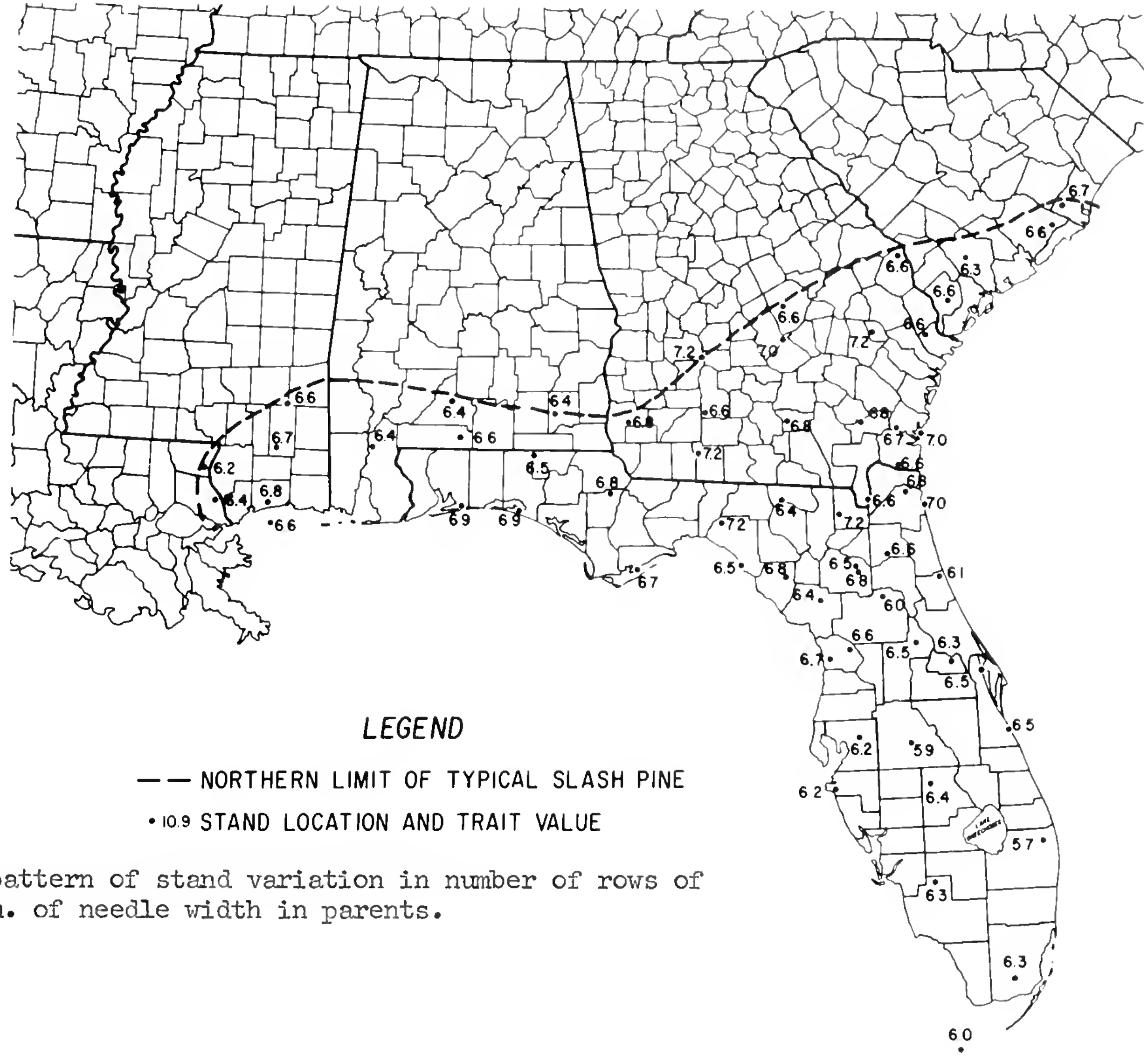


Figure 23.--The pattern of stand variation in number of rows of stomata per mm. of needle width in parents.

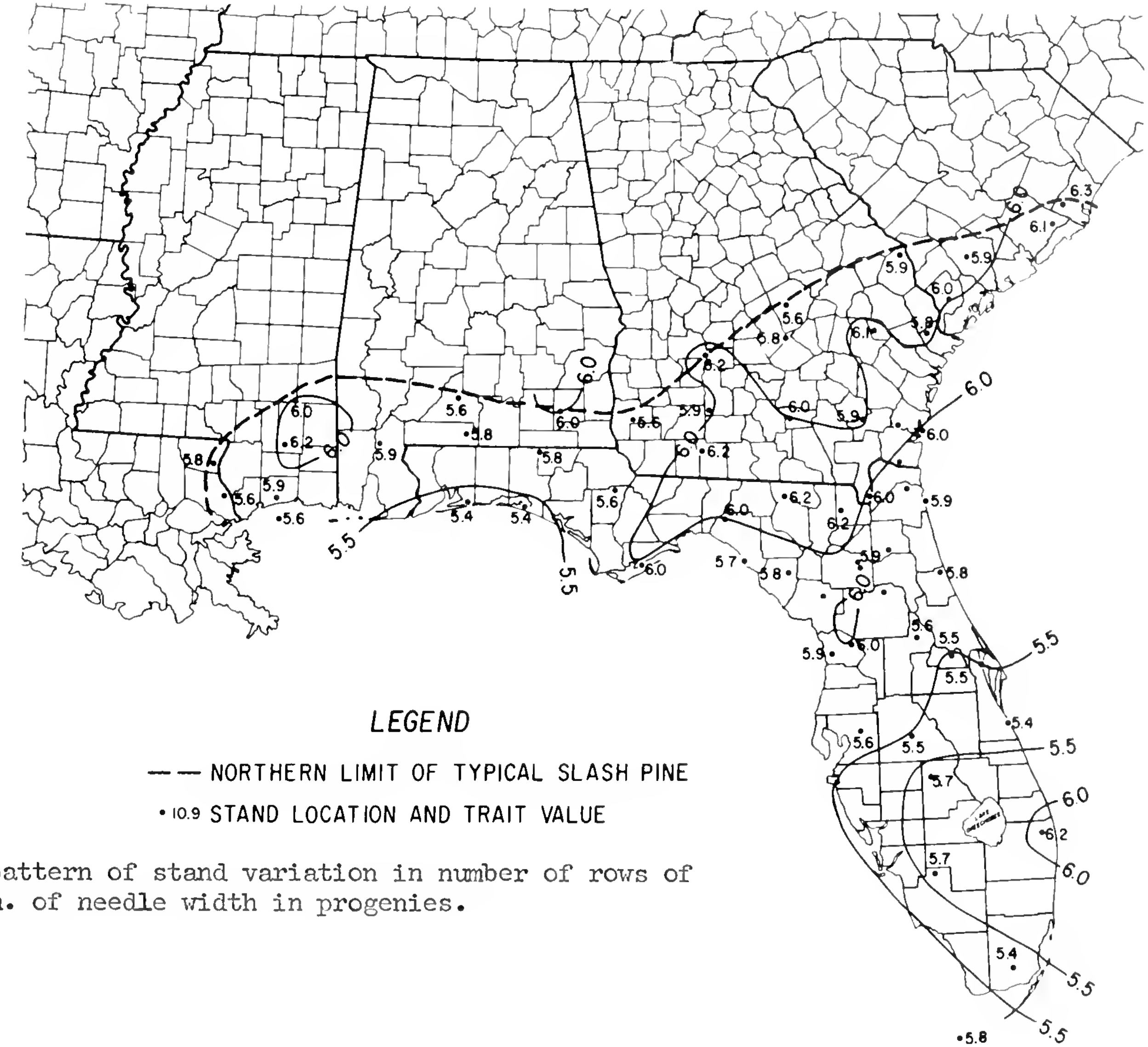


Figure 24.--The pattern of stand variation in number of rows of stomata per mm. of needle width in progenies.

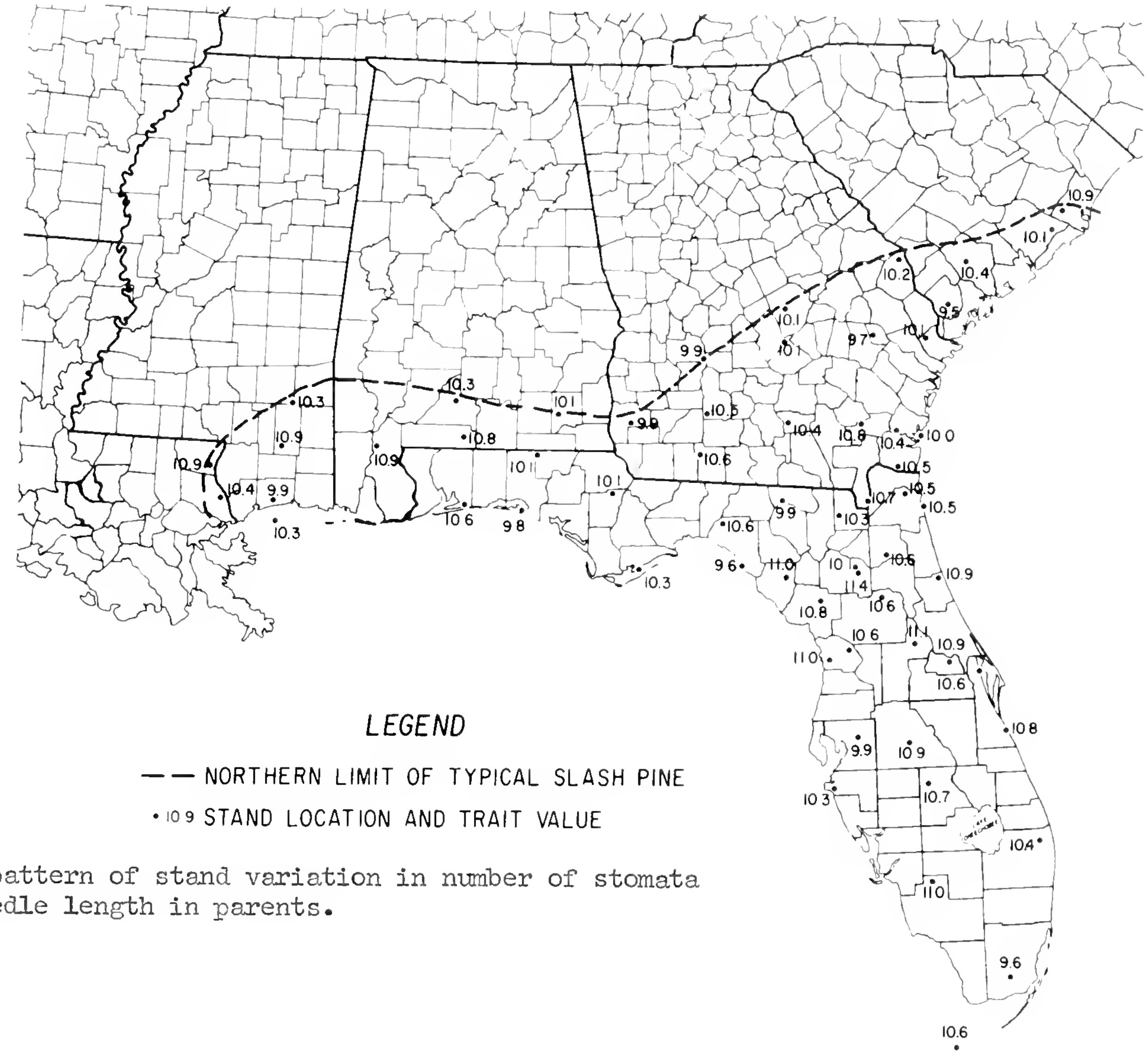


Figure 25.--The pattern of stand variation in number of stomata per mm. of needle length in parents.

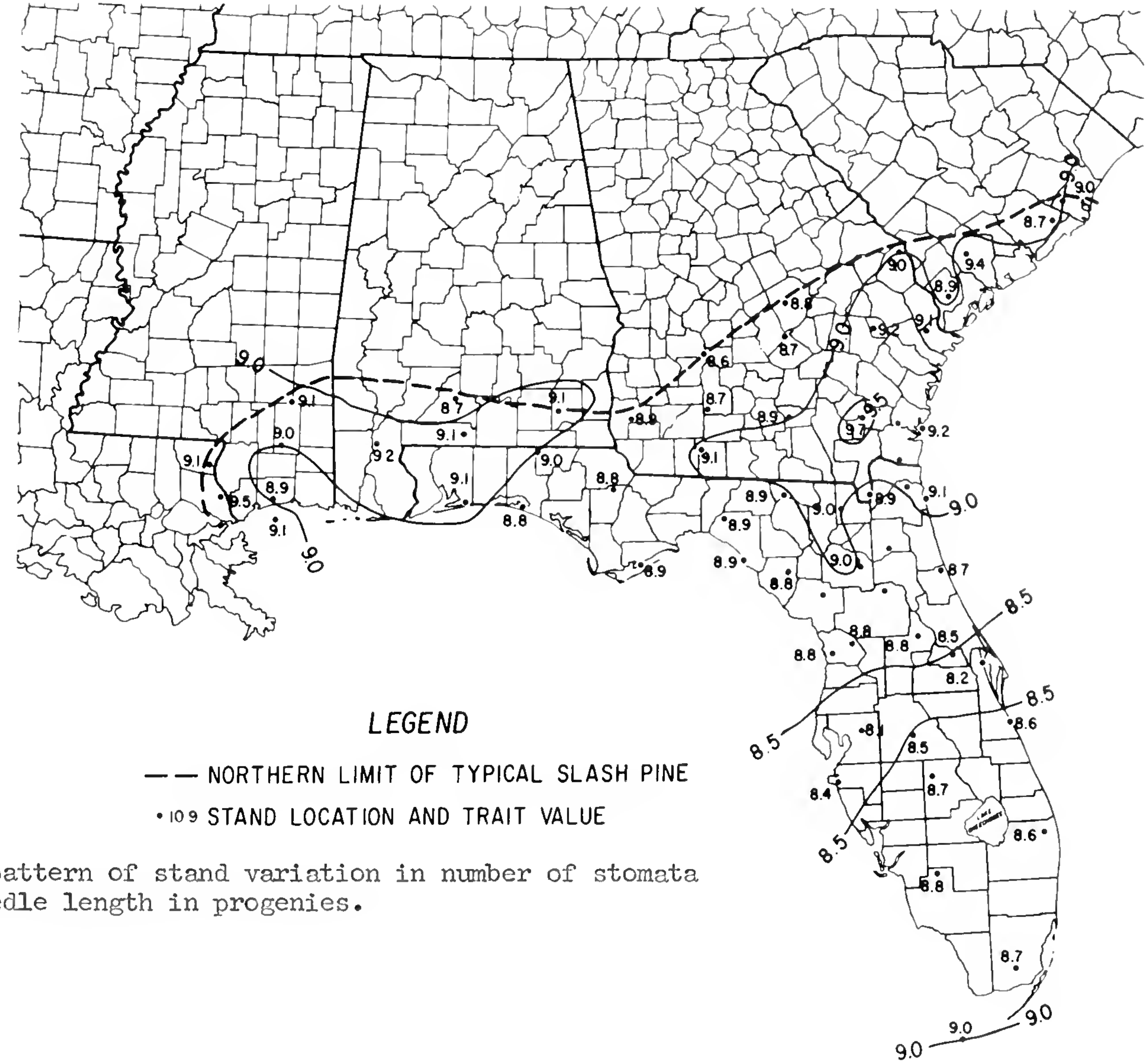


Figure 26.--The pattern of stand variation in number of stomata per mm. of needle length in progenies.

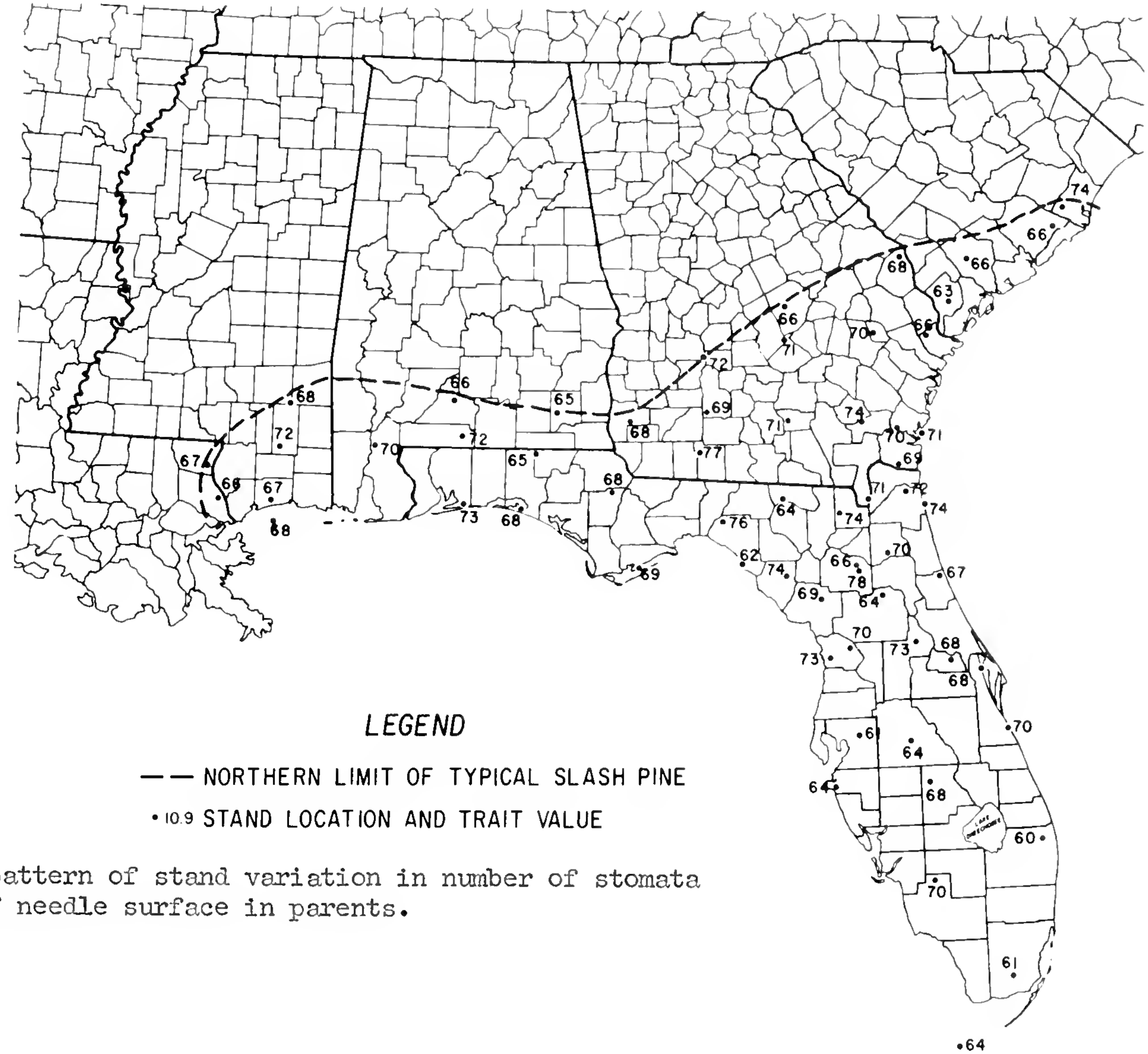


Figure 27.--The pattern of stand variation in number of stomata per sq. mm. of needle surface in parents.

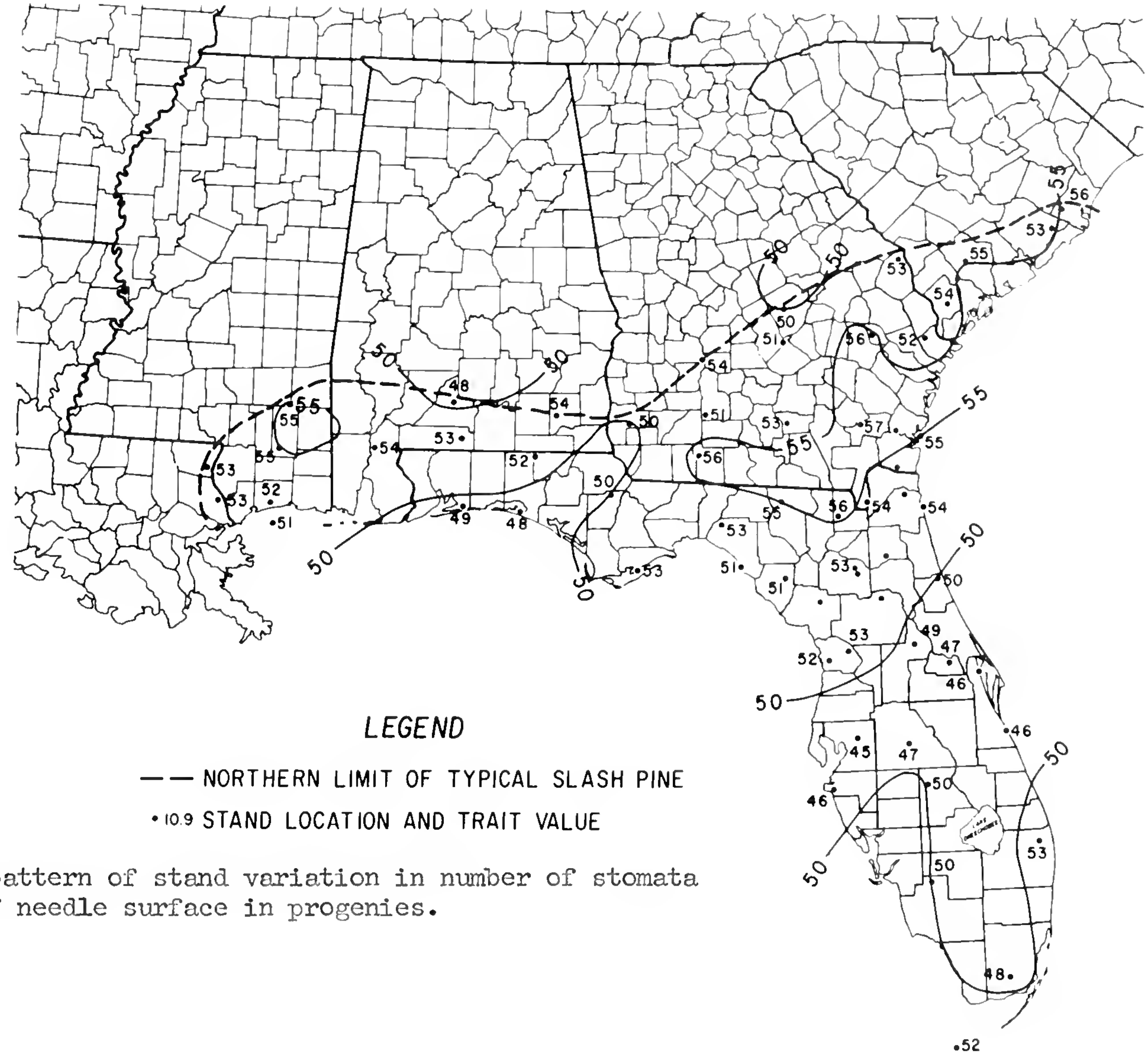


Figure 28.--The pattern of stand variation in number of stomata per sq. mm. of needle surface in progenies.

Thames (1963), sampling loblolly pine seedlings originating from areas in Caldwell and Cherokee Counties, Texas, northwest Georgia, and Crosett, Arkansas, found stomatal frequencies (both stomata per mm. and stomata per sq. mm. of needle surface) to be lowest in the two Texas sources, which agrees with Thorbjornsen's results. Although there were only two sources east of the Mississippi the two traits showed no consistent east-west trend in this region.

Thames (1963) found no significant racial difference in number of rows of stomata in loblolly pine and this was also found to be true for provenances of European larch (*Larix decidua* Mill.) (Gathy, 1959).

Low stomatal frequency may be an adaptation to xeric conditions as suggested by Thames (1963). High stomatal frequency may be associated with photosynthetic efficiency as found in *Ribes* by Bjurman (1959).

Number of resin ducts

The number of ducts in parental foliage averaged 6.90 per needle, ranging from 2 to 13 among individual needles, and from 3.0 to 10.2 among mother tree means (Table 3). Trees of the *densa* variety averaged slightly more ducts than those of the *elliottii* variety or those in the transition zone, but the differences attributable to such groupings were not significant (Table 4). Stands-within-groups was significant but accounted for only 9 per cent of the variance. The pattern among stand means was rather intricate, highs occurring in south-central Georgia, and also along the coasts of Florida (Fig. 29). The low in extreme southeast Florida agrees with data reported by De Vall (1941b).

The high mother tree component (89 per cent) may be largely due to environmental modification rather than to genetic differences among

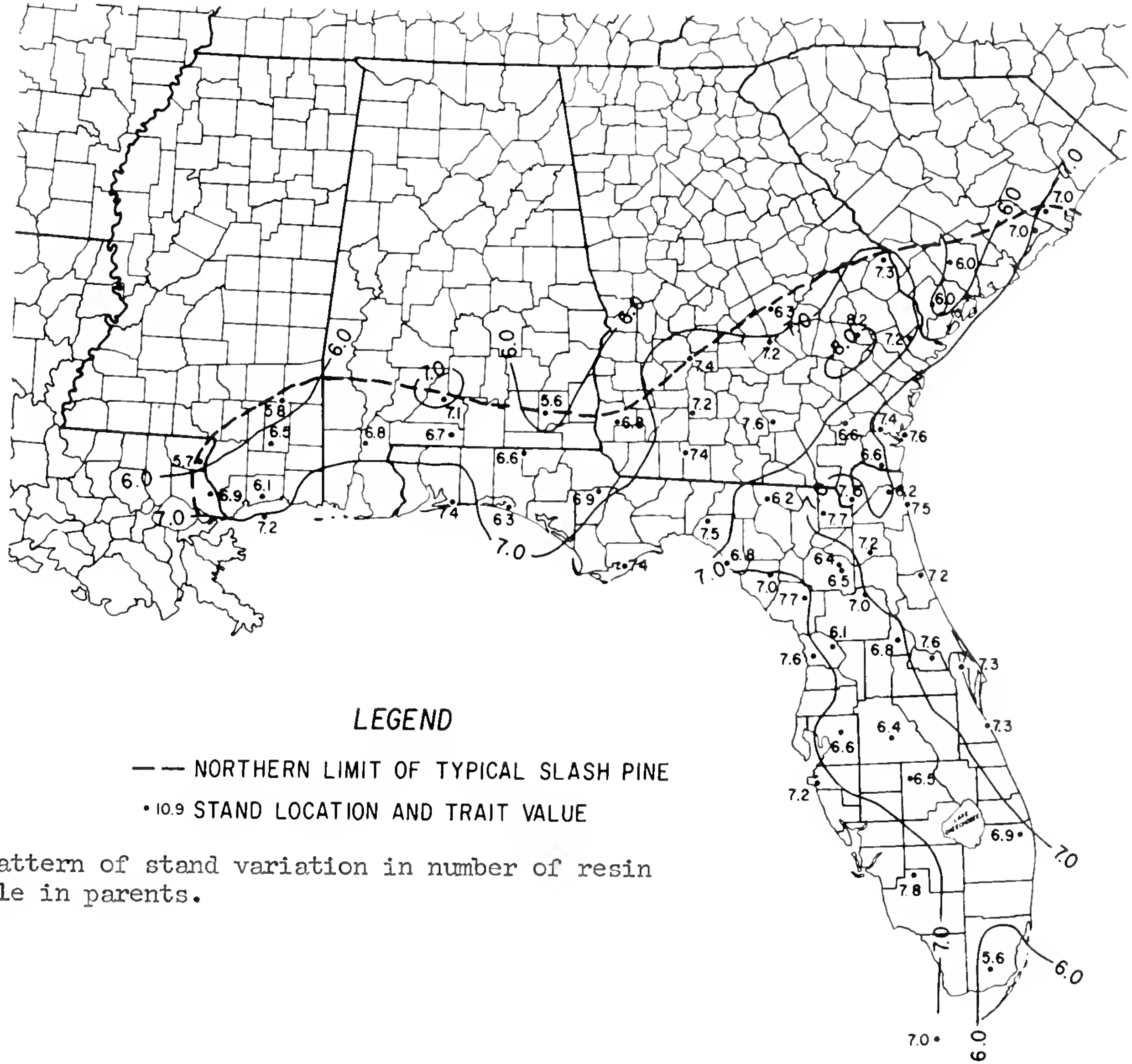


Figure 29.--The pattern of stand variation in number of resin ducts per needle in parents.

trees. White and Beals (1963) showed that resin duct frequency in pond pine (Pinus serotina Michx.) was related to tree age, growth rate, vertical position in crown, and "crown exposure side." Their findings suggest further that even the stand variance may be due to environmental modification rather than racial effects.

In the progenies the numbers of ducts were much fewer, averaging 2.40 and ranging from 0.0 to 5.0 among seedling means (Table 7). Complete absence of ducts was extremely rare, being found in the sample of two needles from a single seedling. "Twos" and "threes" were the most common.

Very little of the variation in progenies was associated with groups or stands, error accounting for most of it (Table 8). The pattern of variation among stand means was largely random (Fig. 30). These results do not agree well with those of Mergen (1958), who found that slash pine seedlings from the central and northeastern counties of Florida and southeastern Georgia had the fewest ducts.

The absence of a distinct difference in number of resin ducts in parental foliage between the varieties of slash pine agrees with Little and Dorman's (1954) findings, but not entirely with those of others as indicated in the tabulation below.

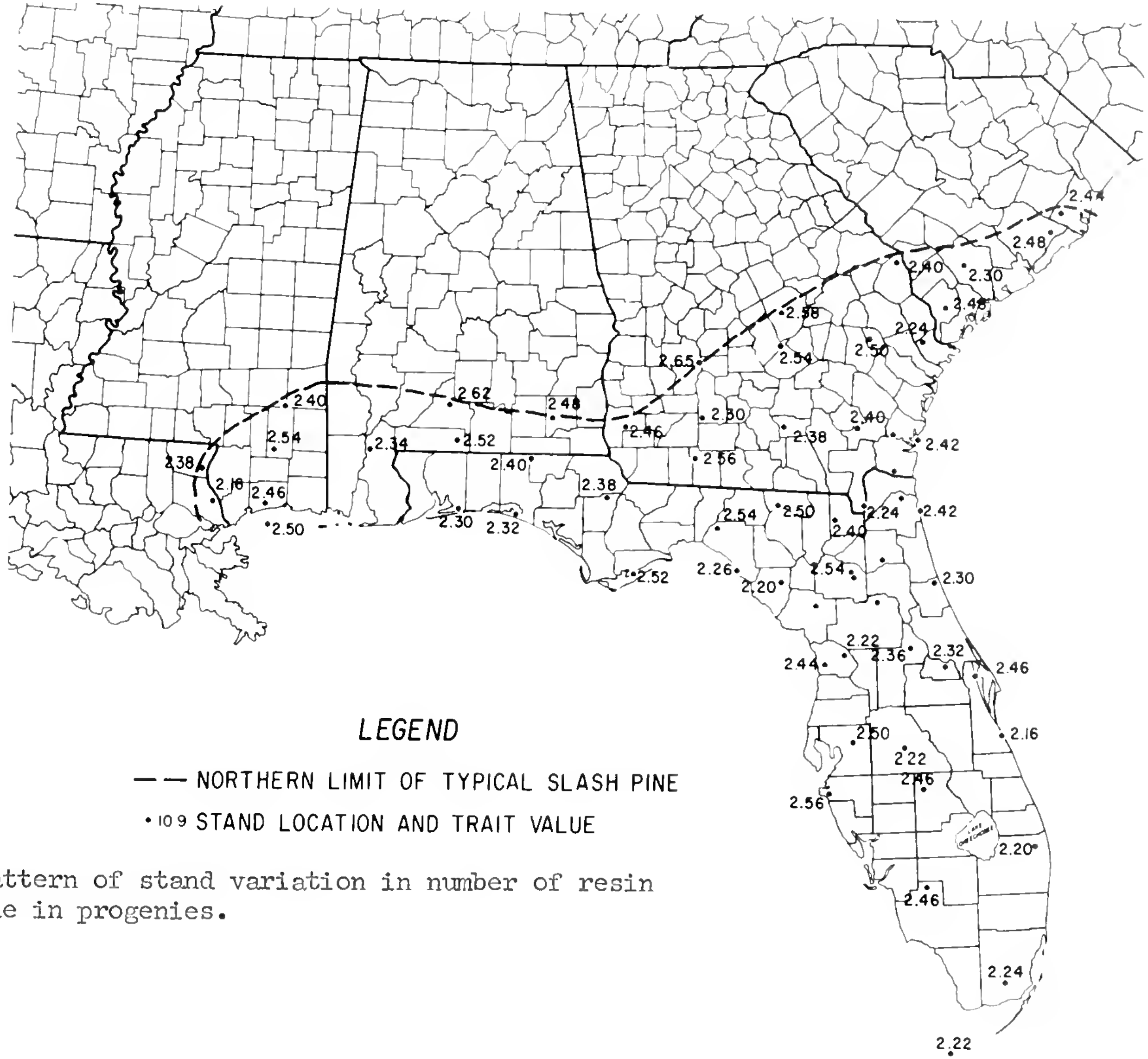


Figure 30.--The pattern of stand variation in number of resin ducts per needle in progenies.

Author	elliottii	densa
	- - Numbers of ducts - -	
De Vall (1941a)	3-5	4-9
De Vall (1945)	2-3[a]	4-9[a]
Little and Dorman (1954)	2-8[b]	3-9[b]
West and Arnold (1956, p. 6)	3-4	5-10
Present study (ranges among mother tree means)	3-10	4-9

a Resin droplets visible with a hand lens on a cut surface in this case.

b For natural stands; the authors showed generally fewer ducts for plantations, which may have been an age effect.

Thickness of hypoderm

Although the thickness of hypoderm in the parents averaged only slightly greater in the densa variety than in elliottii the differences were significant, 37 per cent of the variance being associated with groups of stands (Tables 3 and 4). The stand means displayed a clinal pattern, increasing from north to south, through much of Florida and a random one in the north (Fig. 31).

In the progenies the results were completely different. Groups and stands accounted for relatively small (although significant) portions of the variation, 7 per cent each (Table 8). North Florida progenies had slightly thicker hypoderms, on the average, than south Florida ones (Table 7). But the over-all pattern of stand means showed no clear cut trends, and contained a large element of randomness (Fig. 32).

The outer, thin-walled hypoderm layer was invariably present in both parent and progeny material. In the parents at least one fairly continuous,

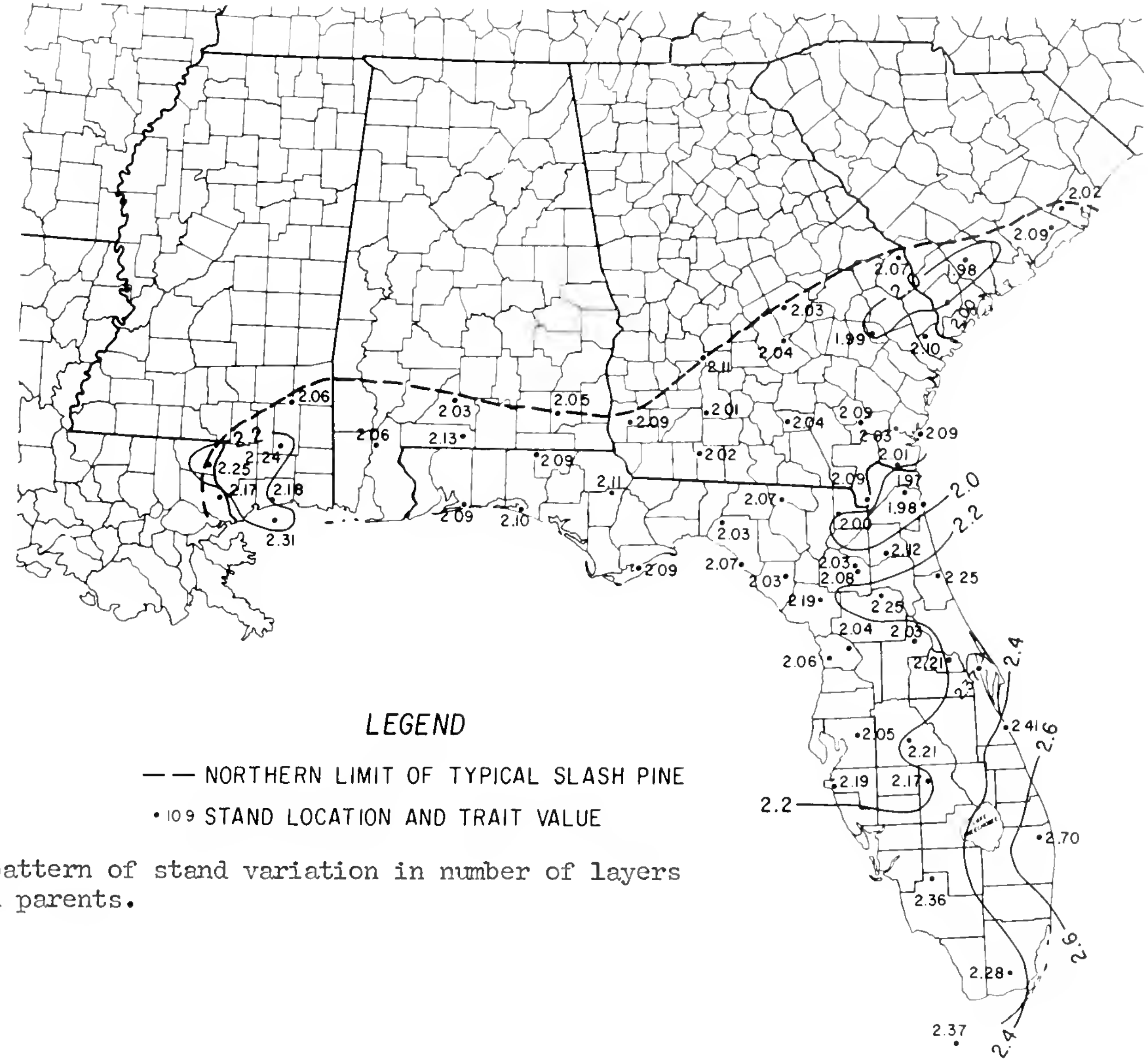


Figure 31.--The pattern of stand variation in number of layers of hypoderm in parents.

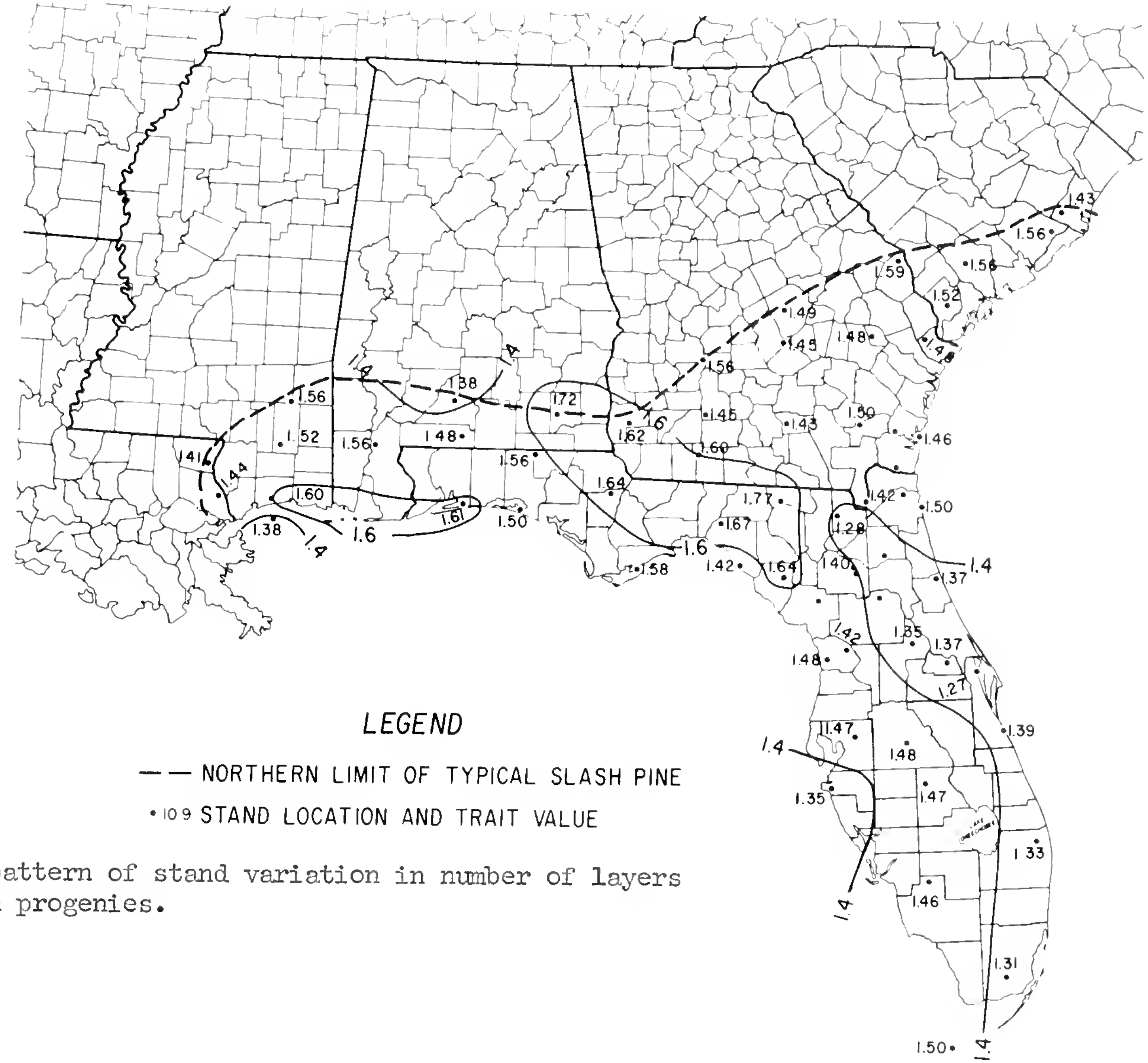


Figure 32.--The pattern of stand variation in number of layers of hypoderm in progenies.

inner, thick-walled layer was present. In the progenies, however, the inner "layer" often consisted of sporadic thick-walled cells.

The results for parent trees agree fairly well with Dorman and Little (1954), although the magnitude of the differences they reported between elliottii (two, rarely three layers) and densa (three to four, rarely two or five) were greater than found here (Table 3). This may have been due to the fact that only current year's needles were used in the present study. The poorly developed hypoderm found in seedlings is probably an age effect. Because of this one should not conclude that the variation in thickness of hypoderm in mature trees is not genetic in nature. In a racial variation study with ponderosa pine, Weidman (1939) did find that geographic differences in this trait were inherited to a large extent.

Little and Dorman (1954), who studied Caribbean pine as well as slash pine, suggested a possible tie-in with climate, thick hypoderm being associated with a dormant dry season for these subtropical and tropical pines. In ponderosa pine thick hypoderm seems to be associated with severe climates (Weidman, 1939).

Discussion of Individual Trait Variation

At this point the individual trait patterns and the components of variance found in the analyses shall be summarized, and the causes and nature of the patterns shall be explored from the genetic standpoint.

Six of the 12 traits studied in the parents and 11 of the 13 studied in the progenies showed significant differences (either at the 5 or the 1 per cent level) among groups of stands. The prevalence of these differences was not surprising since they encompassed the whole species

range and in some instances reflect varietal differences.

However, 10 of the 12 parental traits and 12 of the 13 progeny traits studied showed significant differences among stands within groups. Thus, geographic variation (both phenotypic, as evidenced by parental traits and genetic, as evidenced by progeny traits) seems to be the rule rather than the exception in slash pine, even when considering the varieties as separate taxonomic entities.

In some traits, variation associated with location of the stands was relatively high and in others it was low. Here we are considering variation over the whole species range, which is expressed by the magnitude of the group and stands-within-groups components of variation, taken together. In the parents, this total stand-to-stand variation was relatively high for cone dimensions, seed yield and weight, needles per fascicle, needle length, sheath length, and hypoderm thickness; it was relatively weak or absent for stomatal measurements and resin ducts. In the progenies, total stand-to-stand variation was high for total height, stem diameter, needles per fascicle, needle length, speed of germination,and cotyledon number, while such variation was relatively weak for sheath length, stomatal measurements, resin ducts, and hypoderm thickness. Germinability also showed strong differences associated with locality of source but variation, in this case, may not have been genetic.

The patterns of stand-to-stand variation differed among traits but most of them showed continuity in one form or another. Seven of the traits showed clear, clinal trends with a single distinct reversal: cone length, seed yield, and seed weight in the parents; speed of germination, cotyledon number, stem diameter, and needles per fascicle in the progenies.

Nine others also showed continuity, but the trends were rather highly fluctuating and sometimes intricate, with two or more reversals: cone diameter, needles per fascicle, needle length, fascicle sheath length, and resin ducts in parents; needle length, rows of stomata, stomata per mm., and stomata per sq. mm. in progenies. Two traits showed a random pattern in the north and a clinal trend in the south: hypoderm thickness in parents and total height in progenies. Five showed statistically significant differences among groups and/or among stands within groups but no distinct geographic trends or ecotypes were apparent: rows of stomata and stomata per mm. in parents; germinability, fascicle sheath length, and hypoderm thickness in progenies. Finally, two showed no significant stand differences: stomata per sq. mm. in parents and resin ducts in progenies.

As was also indicated above, the patterns contained reversals, where clinal trends changed direction. These were evidenced by definite "highs" or "lows" within interior portions of the species range. In approximately half of the traits a reversal occurred in the north-central region. Some traits showed several clearly defined reversals. Since clinal trends were associated with these, and since this type of variation likely results from adaptation to continuous environmental factors, the reversals were taken to be indications that two or more environmental factors were involved in causing the pattern and that interactions and/or curvilinear effects occurred. For example, winter temperatures may have a strong effect on a particular trait in the extreme north, with only a weak effect in the south. The opposite could be true for winter precipitation and if both of these factors affected a single trait a reversal could occur.

It is pertinent at this point to consider the nature of the clinal patterns from the genetic standpoint. Natural selection operates on individual traits, and, in doing so, it changes the gene frequencies at the loci involved. Different selection pressures in different portions of the species range then may cause differences in gene frequencies (Dobzhansky, 1951, p. 176).

Thus, considering a particular trait, a clinal pattern may be viewed as a gradient in frequencies of the gene or genes affecting that trait. As a result of the gradient in gene frequencies there will be a similar gradient in genotypic frequencies. In other words, although it may sometimes be convenient to consider a cline as a gradually changing "type tree," it is more realistic to consider it as a gradual change in the proportion of the different possible types of individuals. Of course, if the trait under consideration is affected by a number of genes and/or if environmental effects occur, various intergrades may be found.

A consequence of this situation is that unless complete fixation, or "loss of genes," has occurred in one or more areas, one can expect to find deviant individuals in all parts of the species range. An example seems to be available in slash pine--Perry and Wang (1957) found that about 4 per cent of seedlings in a South Florida slash pine nursery bed did not show a "grass stage" and that various intergrades were present. If the interpretation of a cline, based on a gradient in gene frequencies, is correct then one should be cautious in speculating on the origin of deviants--they may frequently be just as much a part of the population in the area found as are normal seedlings.

The magnitude of genetic variation among trees within stands vs. that due to stand location is of particular interest to tree improvement workers--the comparison is important in judging the relative merits of within stand and between stand selection. The parental data are of little value in considering this question because the estimated components of variance contain environmental effects along with genetic ones and the two kinds cannot be separated.

The progeny data, on the other hand, can be used to study the question posed, excepting where maternal effects (nongenetic effects associated with maternal parents and due to maternal half-sibs having a more uniform environment than progenies not so related) are present. Maternal effects are probably not great in trees except where the trait is related to morphological and physiological factors of the seed. Thus, in the progeny data, germinability, speed of germination, and cotyledon number likely contain maternal effects and this is evidenced by the fact that the mother tree component for these was unusually large in comparison to error. The maternal effect in cotyledon number is due to the strong relation of this factor with seed weight. Seedling height and stem diameter possibly contain small maternal effects because of their relatively weak association with seed weight. The remaining progeny traits likely contain no maternal effects.

For the reasons discussed above only the progeny data of Table 8 should be considered in comparing within-stand vs. between stand variation. In the 10 traits of Table 8 the mother tree component of variance was usually not greatly different from the stand-within-group component. In four of the traits the mother tree component was much less than the group

component. Thus, even if one considers the varieties as separate taxonomic entities, genetic variation within stands was usually not much greater than stand-to-stand variation. The data suggest that genetic gains are feasible through selection among stands as well as among individuals within stands in slash pine.

Diversity Among Individuals Within Stands

The degree of variation among trees within stands is of interest in determining the genetic structure of the transition zone. If the two varieties are actually distinct and occur sympatrically within the transition zone, one would expect the variation among mother trees within stands to be greater in that area than elsewhere. This is so because mother trees were selected at random with no consideration of varietal differences (which, in any event, are not distinct in mature trees). If introgressive hybridization has occurred (recently enough to still be apparent) one would not only expect greater variation among mother trees but also among seedlings within progenies.

In order to study this problem, coefficients of variation (C's) were computed as outlined below:

1. In the parental data variances were computed among mother tree means within stands (5 or less per stand), for each trait, and C's were obtained from these (making 54 C's for each of 12 traits).

2. In the progeny data of Nursery Test 1, two kinds of C's were obtained:

    a. C's were computed among mother tree means within stands (5 or less per stand) as in "1" above (54 C's for each of 10 traits).

    b. Variances were computed among the five (or less) seedlings of each progeny (mother tree) and then pooled for each stand, and C's were computed therefrom. Thus, each C here was based upon 25 or less seedlings and there were 54 C's for each of 10 traits.

3. In the progeny data of Nursery Test 2, C's were computed among mother tree means as in "1" above (54 C's for each of 3 traits).

Pooled, within group averages of the C's outlined above were then obtained in order to compare the magnitude of diversity among elliottii, transition, and densa stands. Results are shown in Tables 9 (lower part), 10 (central and lower parts), and 11 (lower part).

Contrary to expectation, C's were not generally highest in the transition zone. In some cases the group averages differed little, while in others large differences occurred. In two of them, germinability and speed of germination (Table 11), average C's were high in elliottii stands and low in transition stands. But on the whole there was a tendency for these measures of variation to be highest in densa stands, intermediate in transition stands, and lowest in the elliottii stands. This is apparent in the following tabulation, showing the numbers of average C's for each group classified according to their relative magnitude. (For stomata per mm. of length in parental data, where groups 1 and 2 had equal averages, a value of 1/2 was entered in both "highest" and "intermediate" classes; a similar procedure was followed in other cases where group averages were equal.)

Group	Highest	Intermediate	Lowest
1	6-1/2	13-1/2	15
2	9	13	13
3	19-1/2	8-1/2	7
Totals	35	35	35

Table 9.--Coefficients of variation for parental data--per cent

Group	Cone length	Cone diameter	Seeds per cone	Seed weight	Needles per fascicle	Needle length	Sheath length	Rows of stomata per mm. of width	Stomata per mm. of length	Stomata per sq. mm.	Resin ducts	Hypoderm layers
AMONG STANDS												
1	7.0	5.0	33.7	12.1	73.6	6.0	7.1	3.9	3.7	5.6	8.8	3.4
2	9.1	10.1	54.6	7.2	56.7	6.0	9.4	4.3	3.7	6.1	5.5	4.5
3	15.1	9.8	51.9	27.3	57.6	5.8	15.0	3.2	4.0	5.7	9.2	5.8
All groups[a]	29.4	9.4	41.6	14.7	81.4	23.9	8.9	4.5	3.9	5.4	8.8	5.7
POOLED, AMONG MOTHER TREES WITHIN STANDS												
1	12.4	8.5	37.9	18.8	109.8	8.1	8.2	8.8	6.6	10.5	15.5	5.2
2	11.3	8.4	46.6	17.6	79.9	8.6	9.6	7.7	6.6	9.5	20.1	9.1
3	12.6	8.8	43.7	19.0	161.2	11.4	9.4	8.5	6.1	8.8	14.8	9.4
All groups[b]	12.4	8.5	39.4	18.7	110.0	8.9	8.6	8.7	6.5	10.1	15.9	6.7

[a] Within entire species range (not pooled).

[b] Pooled, within groups.

Table 10.--Coefficients of variation for progeny data of Nursery Test 1--per cent

Group	Total height	Stem diameter	Needles per fascicle	Needle length	Sheath length	Rows of stomata per mm. of width	Stomata per mm. of length	Stomata per sq. mm.	Resin ducts	Hypoderm layers
					AMONG STANDS					
1	4.8	5.1	4.6	4.6	7.4	3.7	2.3	4.2	7.1	6.6
2	17.8	9.0	7.1	6.4	5.8	3.4	3.0	5.2	5.2	3.0
3	39.1	9.2	21.9	6.6	8.9	4.1	2.7	5.7	5.9	5.8
All groups[a]	24.0	9.5	13.2	9.4	7.6	4.0	3.0	5.7	5.2	7.1
				POOLED, AMONG MOTHER TREES WITHIN STANDS						
1	10.9	8.8	9.1	6.3	9.0	6.6	4.3	7.5	10.2	9.5
2	15.2	8.3	15.4	7.2	6.1	7.0	4.1	7.6	9.5	6.8
3	14.5	11.9	19.7	7.5	11.9	6.1	3.9	6.4	11.2	8.8
All groups[b]	11.7	9.5	11.4	6.7	9.2	6.6	4.2	7.4	10.2	9.2
				POOLED, AMONG SEEDLINGS WITHIN MOTHER TREES						
1	21.0	16.0	19.4	11.4	15.5	10.7	8.2	12.7	17.9	16.0
2	24.2	17.5	20.4	13.9	13.5	12.4	9.8	14.9	17.2	16.5
3	28.9	20.0	36.4	13.3	20.0	13.2	9.8	15.6	18.9	16.8
All groups[b]	22.2	17.2	21.8	13.0	17.0	11.2	8.6	13.4	18.1	16.1

[a] Within entire species range (not pooled).

[b] Pooled, within groups.

Table 11.--Coefficients of variation for progeny data of Nursery Test 2--per cent

Group	Germinability	Speed of germination	Cotyledons
	AMONG STANDS		
1	16.0	17.6	4.6
2	23.6	13.7	7.2
3	18.1	10.6	7.2
All groups[a]	18.5	19.4	6.0
	POOLED, AMONG MOTHER TREES WITHIN STANDS		
1	28.8	28.2	5.7
2	13.7	13.8	7.2
3	19.0	15.5	4.6
All groups[b]	25.3	23.7	5.8

[a] Within entire species range (not pooled).

[b] Pooled, within groups.

A chi-square test of independence was computed on the data of the above tabulation (Snedecor, 1956, p. 225). The null hypothesis of independence was rejected ($P < .025$). But since the average C's were not highest in the transition zone, the results present no evidence of recent hybridization or of the presence of a "mixture" of individuals of the two varieties in the transition zone.

In order to examine within-stand diversity more closely, the individual stand C's were plotted on maps as was done for trait values. Diversity was frequently found to be lowest in the north-central region, the coastal area of Georgia, and north-central Florida. It tended to be high in south Florida, and moderately high in central Florida, the west, and the northern fringe area. Speed of germination and germinability were notable exceptions--as expected from the group averages discussed earlier, their patterns were largely opposite to those shown for most traits.

It is pertinent at this point to explore the possible causes of the patterns of diversity. The pattern shown by the bulk of the traits shall be considered first. One possibility lies in the existence of islands during the Pleistocene, many of which occurred in Florida. Presumably, many of the islands were very small at times, permitting fixation of genes by genetic drift. Migration following subsidence of the ocean level could then cause a mixing of different genotypes from different islands and from the mainland. This, however, would not explain why the coastal areas of Florida tended to show more diversity than those in the interior. Stands in the coastal areas must have resulted through migration from the interior islands or peninsulas

after each subsidence of the ocean level. Similarly, this gives no explanation for the moderately high diversity in the west and the northern fringe area.

Another possibility (not necessarily exclusive) is that high diversity was due to the presence of critical and highly fluctuating environmental factors. As noted earlier, the extremities of the species range are generally characterized by more severe climatic factors than interior portions. In some cases these factors are fluctuating or occur sporadically, such as the alternating drouth and flooding in the south (Langdon, 1958b), tropical storms in the south and coastal regions, and ice storms in the extreme north. Under such conditions the populations involved must maintain high diversity in order to survive. That is, they must maintain a variety of genotypes, some well suited to the extremes of the environmental factors and some to normal conditions. The diversity may be maintained by heterozygote preference (balanced polymorphism), as shown by Dobzhansky (1951, p. 117) in *Drosophila* populations. Under less critical and/or stable conditions, on the other hand, there is less need for maintaining highly divergent types, with natural selection favoring those most suited to the favorable or stable conditions.

Why did speed of germination and germinability show a trend opposite to that for most traits--the tendency for high C's in the north-central area and low ones elsewhere? A reasonable explanation is that strong natural selection for rapid germination has occurred in the south due to prevalence of adequate moisture in October and winter drouth. That is, the selection was probably strong enough to eliminate or greatly reduce the number of types that fail to germinate

promptly, ahead of the coming winter and early spring drouthy season, thus causing low variation in this trait. In the north-central area, on the other hand, maintenance of variability in respect to speed of germination may be most conducive to survival of the population. Here conditions favoring fall germination occur sporadically and there is probably a need for maintaining both dormant and nondormant types. Germinability may merely be related to speed of germination through pleiotropy, explaining why it tended to follow the pattern for speed of germination.

The hypothesis suggested by the results is consistent with commonly accepted theory of evolution and speciation in that species are so constituted as to attain a balance between fitness of individuals to the prevailing environment and heterogeneity, providing maximum likelihood of survival of the species as a whole in a changing environment (Dobzhansky, 1951, p. 108, and others). The heterogeneity is provided by mechanisms inherent in the species such as balanced polymorphism and others. It is only a step further to surmise that the magnitude of the heterogeneity will depend upon intensity of the factors causing it--the severity and degree of fluctuation of environmental conditions, and the nature of the trait (i.e., the degree of its adaptiveness) under consideration.

Although the explanations for diversity within stands seem logical, they are actually little more than guesses, further study being needed on this subject.

Diversity Among Stands

Thus far the degree of variation among individuals within stands has been considered. Another question of interest concerns differences in the degree of variation among stands within portions of the species range.

In order to examine this question, coefficients of variation were computed among stand means within the three groupings of stands already described. The data are shown in the upper parts of Tables 9, 10, and 11.

The results followed a pattern similar to that for variation within stands--C's were highest in *densa* stands, intermediate in transition stands, and lowest in *elliottii* stands. The pattern is seen more clearly in the following tabulation, showing the numbers of between-stand C's for each group classified according to their relative magnitude.

Group	Highest	Intermediate	Lowest
1	4-1/2	6	14-1/2
2	7	10-1/2	7-1/2
3	13-1/2	8-1/2	3
Totals	25	25	25

A chi-square test of independence was computed on the above data and the null hypothesis of independence was rejected ($P < .01$).

What factors might have caused greater variation among stands in the south compared to the north? The fact that individuals within stands in the south were also more variable may have had some effect, since the variation in stand means depends partially upon variance among individuals. However, if the variation among stands was due entirely to variation among individuals, the differences between groups would have been

considerably less. For example, in that case, the stand C's would have been approximately $\frac{1}{\sqrt{5}} = 0.45$ as great as the mother tree C's, because there were usually five mother trees per stand. Similarly, the stand C's would have been only $\frac{1}{\sqrt{25}} = 0.2$ as great as the seedling C's because there were usually 25 seedlings per progeny. That this was not so is apparent in the data.

It is possible that differences in stand variation were due largely to the fact that sampling was less intensive, geographically, in the south than in the north--that is, on the average, stands sampled were furthest apart in the south. Another possibility lies in the existence of islands during the Pleistocene. As noted earlier, these occurred to a greater extent in central and south Florida than in the north. Effects of genetic drift, presuming they occurred, may have then persisted in some degree to the present time.

Still another possible explanation is that variation in soils and some climatic factors is greater in the south than in the north. Although concrete data on this comparison is lacking, Harper (1927) stresses the importance of high habitat variation in the ecology of the south. High habitat variation could, of course, cause high genetic diversity among stands through natural selection.

Multivariate Analysis

Table 12 gives D values obtained from the Mahalanobis' distance function analysis decribed earlier. Note that the tabulated data are the square roots of the distance functions, D^2, and that they were then multiplied by 10 to eliminate decimals without losing accuracy. The

Table 12.--D values (x 10), with stands arranged in order of decreasing similarity to 8 stands in the north-central region

Stand																																																						
19	19
3	30	3
18	22	31	18
14	26	30	29	14
16	24	32	27	24	16
10	34	27	30	25	26	10
15	30	30	27	26	34	30	15
24	28	30	30	36	38	36	32	24
20	31	27	34	30	34	33	35	30	20
34	32	19	31	34	34	33	34	24	33	34
32	33	26	34	35	38	34	37	25	30	25	32
26	28	38	26	34	35	35	29	33	41	40	34	26
2	32	26	38	35	36	37	38	27	36	25	31	37	2
12	32	30	31	39	42	34	30	27	34	34	34	31	38	12
38	34	25	36	33	41	32	31	29	37	28	23	34	29	31	38
7	34	20	37	32	37	33	33	35	40	27	32	34	18	36	25	7
36	32	28	33	34	35	32	38	33	42	29	28	34	25	39	20	21	36
52	35	30	38	30	42	41	39	32	39	30	28	36	30	39	29	29	38	52
25	35	41	26	36	37	41	31	38	49	39	43	25	41	39	43	37	40	35	25
9	34	32	40	35	30	34	42	40	37	35	45	49	32	46	43	36	38	46	52	9
4	34	27	39	40	40	41	39	33	43	28	34	35	24	35	36	22	34	27	36	39	4
37	35	33	35	36	35	36	38	38	46	34	33	34	28	44	28	24	18	34	36	38	32	37
13	37	30	34	35	42	37	29	40	48	36	40	33	36	37	31	23	30	30	29	43	30	28	13
39	31	40	31	44	42	45	42	32	40	40	40	32	38	35	47	42	44	45	39	45	36	46	45	39
41	36	41	38	43	43	45	43	26	40	34	31	30	27	39	39	37	38	34	36	49	32	39	46	30	41
54	40	30	40	43	48	45	40	32	40	28	25	41	35	32	26	33	35	32	43	55	35	38	40	47	38	54
40	39	37	34	42	46	43	39	32	46	35	29	29	34	39	34	32	32	30	33	51	30	31	30	33	29	35	40
1	39	32	46	40	42	38	47	39	38	35	39	45	19	46	37	27	32	42	54	33	36	40	45	43	38	48	45	1
31	39	41	38	46	45	44	42	30	50	35	33	33	29	40	34	33	30	36	38	48	30	28	39	38	24	36	23	42	31
55	39	40	39	48	49	50	45	29	44	37	32	35	32	36	37	37	38	39	42	52	35	39	43	28	26	32	25	44	27	55
11	46	35	43	39	50	39	30	39	45	39	38	39	37	38	27	31	37	34	45	50	39	38	31	52	46	39	35	44	36	44	11
33	42	37	42	49	48	46	46	33	44	27	35	49	41	40	41	44	43	47	51	54	43	52	54	46	41	34	46	47	44	45	54	33
35	39	36	40	40	36	37	39	46	51	40	40	34	42	42	39	35	36	40	40	44	33	34	32	48	49	47	40	50	43	48	42	57	35
17	41	46	41	46	42	43	48	36	46	40	32	34	42	41	45	47	45	42	42	54	38	45	52	37	27	45	38	50	36	40	54	45	43	17
5	44	33	44	42	51	46	39	40	48	35	38	43	29	44	27	24	29	29	44	49	34	30	29	54	44	35	35	39	36	43	28	50	48	56	5
30	42	42	44	44	49	48	40	43	48	46	33	30	40	39	33	36	38	35	42	56	36	34	37	44	40	35	31	51	37	33	39	58	35	40	42	30
23	48	40	45	43	54	43	41	41	53	41	35	42	43	42	30	37	36	31	44	53	38	32	32	55	48	37	32	56	36	43	32	58	35	46	38	31	23
21	44	40	44	47	52	51	42	42	53	43	38	41	40	47	35	35	36	31	42	52	35	28	30	52	46	40	29	52	32	40	32	58	42	54	26	36	29	21
6	50	40	50	45	58	48	44	40	46	40	33	49	41	39	30	40	42	35	54	60	43	46	46	55	46	27	39	50	42	43	34	44	56	51	37	41	36	43	6
27	48	47	42	49	46	43	46	44	55	48	43	35	47	45	49	43	45	46	37	55	39	39	40	41	40	49	28	57	33	41	48	57	41	40	54	40	40	43	53	27
8	48	41	50	45	54	48	41	46	49	47	41	46	42	44	37	36	44	36	52	51	38	40	37	52	50	44	37	51	42	43	26	63	41	54	37	33	29	29	37	47	8
22	46	43	49	45	53	49	42	46	56	45	45	44	38	48	35	35	37	35	48	46	36	32	31	53	50	48	38	48	38	46	30	65	36	54	32	36	29	28	48	51	24	22
42	60	60	61	63	64	60	61	56	70	58	52	46	49	57	52	49	49	50	52	65	42	45	50	54	44	57	39	58	37	47	54	69	46	41	54	38	42	48	58	41	49	42	42
44	71	68	68	67	68	62	65	64	75	68	66	56	62	62	66	59	66	62	54	75	55	60	59	64	55	66	56	72	55	62	66	76	62	53	71	56	56	68	66	41	67	68	46	44
45	82	87	83	84	80	81	86	82	95	85	83	71	75	84	84	74	75	80	70	85	70	67	75	78	69	86	70	84	64	76	87	93	75	68	84	71	74	78	89	56	84	78	51	40	45
29	86	85	83	88	81	80	87	84	91	84	79	74	82	80	86	80	82	83	72	93	72	74	82	80	71	79	72	92	69	78	90	87	76	62	90	71	75	82	84	54	85	88	59	45	48	29
43	89	88	90	88	87	84	86	83	97	87	88	76	79	83	88	78	86	62	74	87	69	79	77	79	74	90	75	88	71	80	84	96	74	72	90	76	75	84	92	60	82	79	55	37	45	62	43
50	97	96	100	98	97	94	95	90	100	96	95	88	88	87	98	89	98	91	87	97	77	92	91	85	80	95	85	96	82	87	96	100	90	79	99	85	88	94	94	70	90	94	70	45	56	58	38	50
49	105	100	106	104	102	95	100	98	107	102	102	96	96	94	103	94	102	100	95	101	86	97	94	96	92	103	94	102	92	99	102	106	95	89	106	94	93	103	102	76	100	102	80	48	61	65	44	31	49
48	108	102	110	107	107	104	106	102	112	104	103	98	95	101	102	91	100	98	95	106	87	92	92	100	94	100	93	103	92	95	104	113	97	97	102	89	91	98	103	81	99	99	78	54	55	71	53	52	47	48
28	114	110	114	112	111	107	109	106	120	109	111	103	100	108	111	98	107	103	98	109	90	99	98	105	97	111	96	108	91	103	104	117	102	100	106	101	97	100	109	80	101	100	80	59	58	76	42	45	46	52	28
46	116	117	118	120	115	113	115	114	127	118	119	106	108	111	117	106	112	114	106	112	98	104	104	108	106	120	105	115	100	110	116	124	103	105	116	105	106	109	120	89	110	106	84	70	56	79	51	54	48	55	45	46
53	123	109	124	116	115	108	116	118	125	111	116	115	107	114	112	99	110	110	111	114	97	106	103	123	114	113	111	112	108	120	111	117	102	112	111	110	103	113	113	99	112	111	98	78	86	90	76	80	64	68	69	79	53
47	125	116	126	122	120	114	120	119	128	117	117	113	109	116	117	105	114	113	112	119	99	107	109	118	109	116	108	115	103	114	114	123	106	107	115	106	104	112	114	93	110	110	86	68	67	73	57	55	48	49	44	53	44	47

magnitude of each indicates the degree of similarity (not necessarily true relationship in the genetic sense) between the respective two stands, taking into account simultaneously the 17 traits used in the analysis. Thus, a relatively low D between two stands indicates a relatively high degree of similarity, while a high one indicates dissimilarity.

In general, the results agreed well with results of the single variate analyses. Examination of the D values immediately revealed that D's between stands in the north-central region and those in the south were greatest. In order to examine this point further a group of 8 stands (Nos. 14, 15, 16, 18, 19, 20, 24, and 34) within the north-central region, which showed a very low within-group average D, were selected. Then the D value between each of the other stands and those eight were averaged to obtain a value indicative of the degree of similarity to stands in the north-central region. For example, for stand no. 1, the D values between stand no. 1 and the 8 selected north-central stands were 39, 46, 40, 42, 47, 39, 38, and 35 (from Table 12); the average of these is approximately 41. Comparable averages for the eight north-central stands chosen were also obtained by computing average D values among them. For example, for stand no. 14, the D values between stand no. 14 and the other 7 north-central stands were 26, 29, 24, 26, 36, 30, and 34; the average of these is approximately 29.

The average D values, computed in this manner, are shown in Figure 33 (also, in Table 12 the stands are arranged according to the magnitude of these averages). Note that the data in Figure 33 revealed a familiar pattern, with a north-south clinal trend and a reversal in the north-

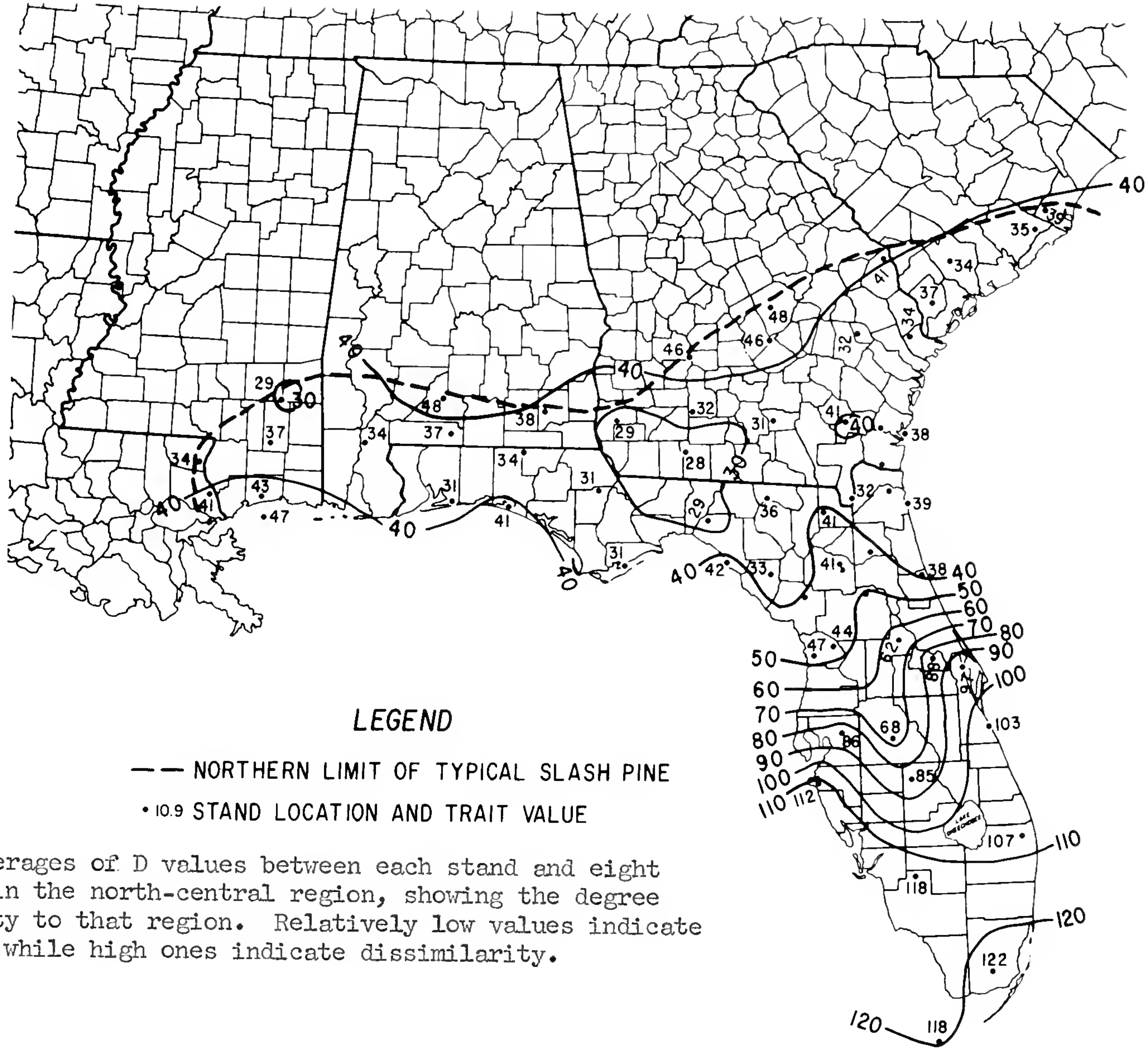


Figure 33.--Averages of D values between each stand and eight stands within the north-central region, showing the degree of similarity to that region. Relatively low values indicate similarity, while high ones indicate dissimilarity.

central region. The gradient is steep in central Florida. In the whole northern region an east-west pattern is also apparent--stands within the north-central region were more closely similar to each other than to those to the east or west.

It is important to note that Figure 33 expresses only the similarity of each stand to those in the north-central region. Thus, stands having roughly equal averages are not necessarily closely related to each other, although this is frequently true as will be seen later.

In order to examine relationships among stands in various portions of the species range, the "cluster technique" described by Rao (1952) was used. The process began by first selecting pairs of adjacent stands which showed relatively small D values. These pairs formed the nuclei for clusters. Additional stands were added to each, the requirement for acceptance being that the proposed addition does not greatly increase the average D and that it fit better than in other clusters. In forming the clusters it was found that the average D usually increased with the addition of new stands, frequently because of the existence of clinal variation. Thus, the number of clusters formed was highly arbitrary. However, in view of the fact that the main purpose of clustering was to show relationships between clusters rather than to designate ecotypes, the procedure was considered satisfactory.

The result of the clustering process is shown in Table 13. A total of 10 clusters, containing from 1 to 10 stands each, were formed. Note that the within-cluster averages (the value on the extreme right of each row of values) is smaller than the between-cluster averages in each case, which shows the effectiveness of the clustering procedure. With a few

Table 13.--Average within- and between-cluster D values (x 10), clusters formed as described in text and arranged in order of decreasing similarity to "North-central (west)" cluster[a]

Cluster	Stands (n)	North-central (west)	North-central (east)	Western	North-eastern	North Fla.	Western (Coastal)	Northern fringe	Central Fla.	South Fla.	Fla. Keys
	Number	Average D (x 10)									
North-central (west)	8	30									
North-central (east)	4	34	28								
Western	6	36	36	28							
Northeastern	6	38	35	35	33						
North Florida	10	41	39	41	39	34					
Western (coastal)	3	44	42	40	36	46	33				
Northern fringe	5	45	46	41	36	42	35	30			
Central Florida	5	77	77	73	71	62	78	70	51		
South Florida	6	109	105	101	103	96	107	100	63	48	
Florida Keys	1	118	116	106	109	112	112	108	86	67	--

[a] The number of D values upon which each of the between-cluster averages is based is equal to the product of the two respective "n's"; for within-cluster averages the basis is $\frac{(n)\ (n-1)}{2}$

exceptions, the stands within clusters are contiguous geographically (Fig. 34). One of the exceptions is the "Western (coastal)" cluster--stand 11, curiously, is widely separated from 5 and 6. The fact that stand 14 fitted better with the "North-central (west)" group rather than with the "Northern fringe" was also puzzling.

The relatively large within-cluster averages for "Central Florida" and "South Florida" are apparently a consequence of high stand-to-stand variation noted earlier in the single-variate analyses.

The approximate degree of similarity among clusters is shown in Figure 35, which is based upon the data of Table 13. Note that the figure does not show all possible D values and is not drawn to scale accurately--an impossibility with only two dimensions. Nevertheless, clusters appearing close together in the figure are relatively similar, while those far apart are dissimilar. As can be seen, clusters near to each other geographically tend to be relatively similar, largely because of clinal trends. However, note several exceptions. For example, "Northern fringe" is more similar to "Central Florida" (average D between these two clusters = 70) than is "North-central (west)" (average D between "Central Florida" and "North-central (west)"= 77), even though "Northern fringe" is furthest from "Central Florida" geographically. The same situation is true for the "Northeast" cluster. This seemingly anomalous situation is apparently a consequence of the trend reversals commonly occurring in the north-central region, pointed out earlier.

The "Western (coastal)" and "Northern fringe" clusters curiously hang together and the reason for this is obscure. The "North Florida" cluster is more similar to those in the south than are clusters in the north, as might be expected because of the clinal trends.

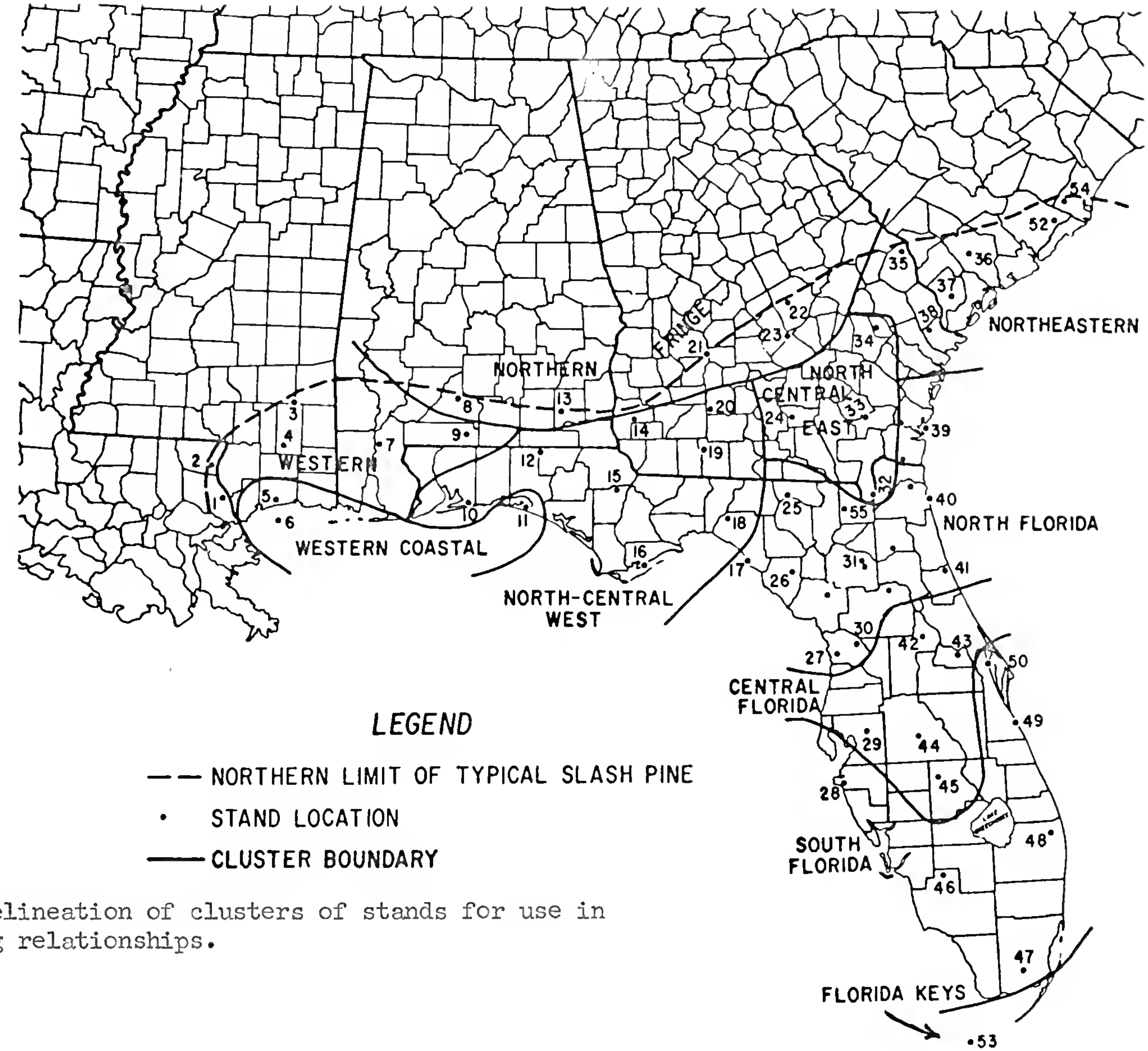


Figure 34.--Delineation of clusters of stands for use in determining relationships.

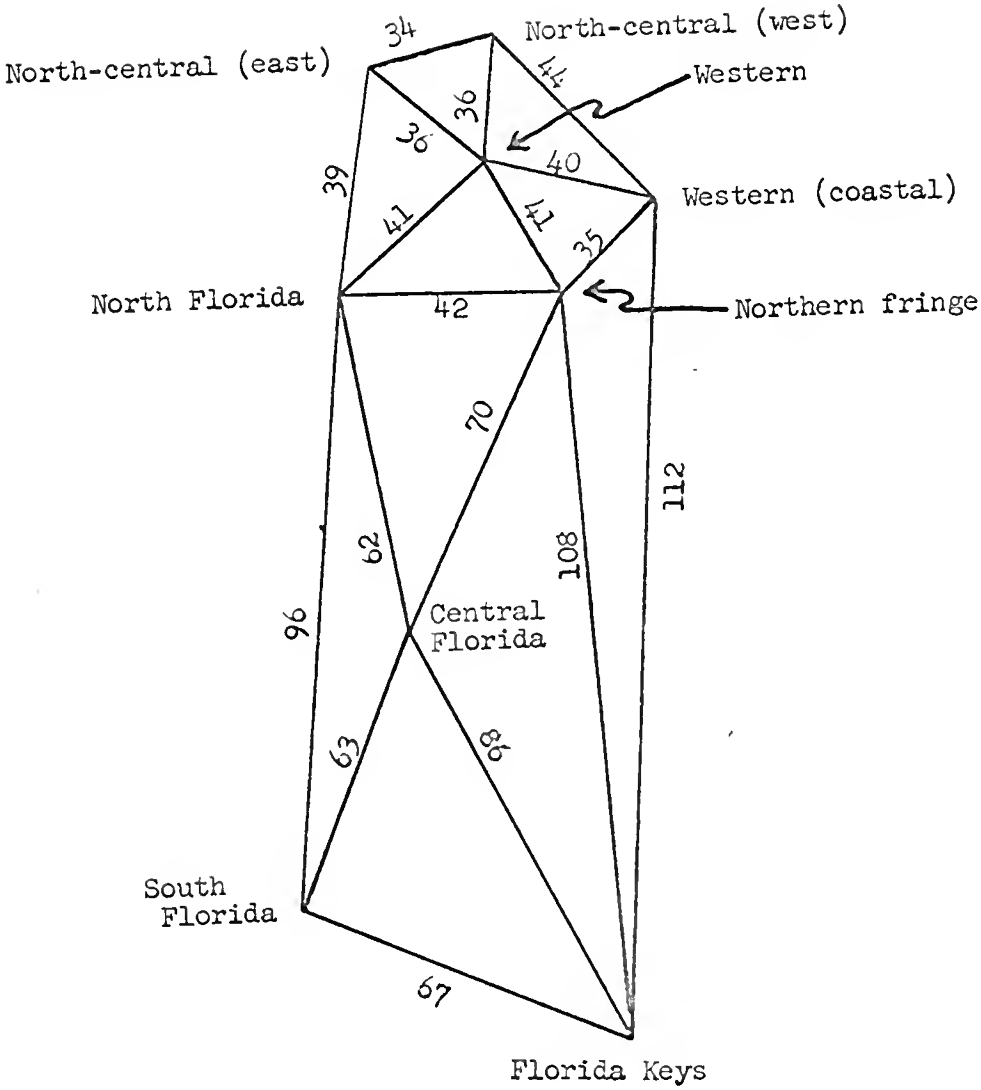


Figure 35.--Diagrammatic representation of the approximate degree of similarity among clusters of stands according to average between-cluster D values. "Northeastern" cluster, not shown above, is very similar to "Western." For average D values not shown above, see Table 13.

A test for clinal vs. ecotypic variation was made by a procedure similar to that discussed by Wells (1962) and Wright and Bull (1963). A transect extending from stand 24 in the north-central region southward through the approximate center of Florida to stand 47 was delineated. D values between the stands represented on this transect are compiled in Table 14. Note that D values for geographically contiguous stands (those on the extreme right) are smaller than those to the left (noncontiguous stands), and that they generally increase from right to left within a row or from top to bottom within a column. This shows that contiguous stands are more similar to each other than noncontiguous ones, and that the further two stands are apart geographically the greater is their dissimilarity. The values change relatively more rapidly near the center of the transect than they do at the ends. This is a consequence of the relatively steep gradient in trait values in central Florida, shown earlier, for a number of individual traits. The change in the rate of change in central Florida, however, hardly justifies delineation of ecotypes as the variation is largely clinal to the north, to the south, and across, the central area.

Two other transects were formed--one extending from the north-central region southward along the east coast of Florida and the other beginning in the same region and extending southward along the west coast of Florida. The results in both cases were similar to those of Table 14.

In the above analysis, stands in the north-central region were used as starting points to test for latitudinal clines. The reason for this was that above this area the trends change direction, as shown in Figure 33, and in many of the individual trait patterns. Because of the limited

Table 14.--D values (x 10) for stands in a transect going from stand 24 (north-central region) southward through the center of Florida to stand 47 (south Florida).

Stand	24	55	31	42	44	45	46	47
24								
55	29							
31	30	27						
42	56	47	37					
44	64	62	55	46				
45	82	76	64	51	40			
46	114	110	100	84	70	56		
47	119	114	103	86	68	67	53	

breadth of the northern fringe area it is difficult to prove a clinal trend with the use of D values but there is little question that it exists. Observation of Figure 33 and many trait patterns shows that changes northward from the north-central area are usually gradual.

The D values show no evidence of an unchanging longitudinal cline in the north. This, however, does not mean that racial variation does not exist in the north, nor does it mean that changes are not gradual. The study of clusters, as well as the individual trait patterns, showed that longitudinal variation does occur in the north. The pattern, however, is not a simple cline. The clusters delineated in the north could be considered as ecotypes, but with the qualification that changes between ecotypes are gradual. Another way to describe it might be to say that the longitudinal variation is continuous but highly fluctuating.

Nomenclatural Considerations

In view of the fact that most of the traits studied showed continuous variation, one may question the division of the species into varieties.

The differences between slash pines in the north and those at the extremes of the species range certainly are striking in several respects and they are genetic to a large extent. It seems proper therefore to ascribe different names to these extreme types. The common name "South Florida slash pine," and even its scientific name, have become well accepted and the separation certainly serves a purpose. It is better, for example, to prescribe silvicultural treatments separately for the two varieties than to prescribe a single treatment for the whole species, or to label seed as being of one or the other variety rather than to label it merely "slash pine."

However, there are those who feel that subdivision in the presence of clinal variation is misleading and does more harm than good, because it gives a false impression of homogeneity within the taxonomic subgroups, disguises gradients among subgroups, and discourages study of variation among subgroups (Huxley, 1938; and Langlet, 1959 and 1963). This viewpoint certainly has merit. Subdivision also tends to impart a certain degree of "smugness," causing laxity among both forest managers and researchers. It becomes tempting, for example, to assume that trees at the extreme southern tip of Florida would require exactly the same silvicultural treatment as those in central Florida because they are both South Florida slash pine, while trees just beyond the "boundary line" require a different treatment because they are of a different "species" (many foresters have actually elevated the subdivision to a species level in their thinking and conversation).

Irrespective of nomenclature, one should keep in mind that South Florida slash pine and typical slash pine may not be discrete genetic entities cleanly separated from each other morphologically, physiologically, or geographically; that many traits show clinal variation both within and between the varieties; and that for some purposes, especially (but not limited to) seed collection, it is therefore highly desirable to specify the exact geographic origin of material rather than merely specifying its varietal name.

SUMMARY AND CONCLUSIONS

The main purpose of this study was to determine patterns of geographic variation for a number of morphological and physiological traits of cones, seeds, foliage, and seedlings in slash pine, and to determine the causes of such variation where found.

Mature cones and foliage samples were collected from each of 5 trees in 54 natural stands scattered throughout the species range in the fall of 1960. Seeds extracted from the cones were sown in a nursery at Olustee, Florida, in the spring of the following year, and foliage samples were collected from the resulting seedlings in the fall of 1961.

Data were taken on 12 traits in the parents and 13 traits in the progenies, and were subjected to analyses of variance to determine the proportions of variance associated with groups of stands, stands within groups, and mother trees within stands. The parental data gave information on phenotypic variation associated with locality while the progeny data, for the most part, gave information on the extent of genetic variation associated with locality of source. Isograms were drawn to elucidate patterns of variation where justified. Regression analyses were employed to study relations with climatic factors. A distance function was used to study a group of traits simultaneously.

Major findings and conclusions follow.

1. Most of the traits studied showed significant differences associated with the geographic source of the material. In the parental data such stand-to-stand variation was relatively strong for cone dimensions, seed yield per cone, seed weight, needles per fascicle, needle length, fascicle sheath length, and hypoderm thickness, while it was relatively weak or absent for various measures of stomatal frequency and frequency of resin ducts. In the progeny data, stand variation was strong for total

height, stem diameter, needles per fascicle, needle length, germinability, speed of germination, and cotyledon number, while it was relatively weak for sheath length, stomatal frequency, resin duct frequency, and hypoderm thickness.

2. Most traits showed some type of clinal or continuous variation, containing one or more trend reversals. The clinal patterns apparently resulted from genetic adaptation to gradients in environmental factors. The trend reversals were probably due to the existence and interaction of two or more factors affecting each trait. Random variation, possibly due to genetic drift, was found in a few instances.

3. Many traits showed a generally north-south trend through Georgia and Florida with a reversal in the north-central region (extreme south Georgia and north Florida). This general pattern probably resulted from the latutudinal gradient in winter temperatures (or similar factors) and in seasonal distribution of rainfall. Curvilinearity or interactions of these could be the cause of the reversal.

4. Longitudinal variation also existed in the north but was usually not as pronounced as latitudinal variation. The longitudinal pattern for most traits could be described as being continuous but highly fluctuating.

5. Multivariate analysis similarly revealed a latitudinal gradient through Florida and Georgia, which contained a reversal in the north-central region and which was relatively steep in central Florida. Thus, stands in the north-central region were less similar to those in south Florida than were those in other portions of the north.

6. Variation among trees within stands tended to be least within the north-central region, the coastal area of Georgia, and north-central Florida, and greatest in south Florida and other extremities of the species range. This was believed to be due to the existence of severe environmental factors in the latter group, which probably fluctuate greatly in time, resulting in maintenance of a greater variety of genotypes than in the central areas.

7. Variation among stands tended to be low in the north and high in the south. This may have been partly due to prevalence of islands in Florida during Pleistocene times, causing stand variation through genetic drift, and possibly to higher variation among habitats in the south than in the north.

8. Trees growing within the ranges of the two varieties showed dissimilarity in several respects, but patterns were usually continuous both within and between varieties. No evidence of the existence of two distinct types (representative of varieties) was found within the transition zone. Likewise, no evidence was found to suggest that trees in the transition zone are hybrids between densa and elliottii varieties. Hybridization and introgression may have occurred during the Pleistocene or earlier but if so, subsequent natural selection has apparently obscured it.

These conclusions were based largely on the fact that diversity among trees within stands was not greatest in the transition area.

9. The sampling design used, although much more intensive than that employed in past slash pine studies, contained several deficiencies. A greater intensity of sampling in central and south Florida would have given a better measure of differences in stand-to-stand variation in different areas. More mother trees per stand and more progenies per mother tree would have given a better measure of variation within stands, an important consideration in studies of this nature. Finally, it may have been preferable to delineate zones for sampling purposes and select samples randomly within zones. These and other deficiencies of the study should be considered in evaluating its results.

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APPENDIX

KEY TO APPENDIX TABLE 1

Column no.	Item
1	Mother tree identification. The first digit indicates group number; the second and third, stand number; and the fourth, mother tree number.
2	Sum of the lengths of seven cones--inches. Decimal between second and third digits.
3	Sum of the diameters of seven cones--inches. Decimal between second and third digits.
4	Average number of seeds per cone.
5	Number of seeds weighed.
6	Total weight of seeds indicated in column 5--milligrams. Column 6 divided by column 5 gives average seed weight.
7	Number of ternate fascicles in a sample of 40 fascicles.
8	Sum of the lengths of 15 fascicles--millimeters.
9	Sum of the lengths of 15 fascicle sheaths--millimeters.
10	Sum of the numbers of rows of stomata on the flat surface (or surfaces) of five needles.
11	Sum of the flat surface widths of five needles--micrometer units. (100 micrometer units = 1.68 mm.) $\frac{\text{Col. 10}}{\text{Col. 11}} \times \frac{1}{.0168} =$ number of rows of stomata per mm. of needle width.
12	Sum of the numbers of stomata counted in 10 stomatal rows, each 1.68 mm. long. These values, divided by 16.8, give numbers of stomata per mm. Also, $\frac{\text{Col. 10} \times \text{Col. 12}}{\text{Col. 11}} \times \frac{1}{10(.168^2)} =$ number of stomata per sq. mm.
13	Sum of the numbers of resin ducts counted in each of five needles.
14	Sum of the numbers of hypoderm layers counted at four points in each of five needles. These values, divided by 20, give average numbers of layers of hypoderm per needle.

Appendix Table 1.--Parent tree data

1	2	3	4	5 6	7 8	9	10	11	12	13	14
1011	290	119	105	1324595	002739	274	49	435	177	36	41
1012	273	112	086	1323056	002660	240	47	420	182	30	41
1013	278	141	104	1323342	013102	244	42	447	174	34	42
1014	336	139	086	1324062	043155	256	53	449	168	32	47
1015	364	134	104	1324177	023433	295	45	496	170	40	46
1021	311	121	081	1323697	022800	265	42	424	198	37	43
1022	309	132	096	1323534	013495	276	53	474	170	25	49
1023	344	119	049	1324117	123297	301	51	493	189	26	43
1024	289	109	055	1322866	103137	245	46	419	163	26	43
1025	306	132	119	1323318	053005	266	48	499	191	28	47
1031	262	103	084	1323084	003023	183	56	448	181	15	41
1032	364	119	092	1323349	063203	286	49	461	181	27	40
1033	272	111	041	1323954	002910	236	44	441	156	33	41
1034	296	108	050	1323641	002812	214	49	443	181	34	41
1035	320	131	072	1325811	103415	213	58	515	170	37	45
1041	369	133	085	1325154	003175	270	61	480	172	37	43
1042	334	122	057	1324687	003367	296	44	451	179	27	49
1043	269	116	070	1323528	002998	264	42	445	190	35	42
1044	355	127	080	1323599	213267	264	62	515	193	33	47
1045	285	113	047	1322853	003126	246	54	436	174	31	43
1051	358	140	059	1323479	253305	255	54	471	161	26	44
1052	427	134	031	1324588	303713	311	54	495	167	23	42
1053	269	116	032	1322929	123491	304	57	465	150	43	47
1054	249	118	064	1323349	013030	248	56	445	166	35	44
1055	319	134	059	1323705	043207	222	44	391	188	26	41
1061	308	109	040	1323679	152998	249	41	427	172	21	46
1062	320	102	026	1323719	002884	247	61	47[illegible]	174	43	46
1063	266	122	015	1323652	052690	259	45	451	163	43	47
1064	234	112	020	1323698	052508	224	53	455	172	34	46
1065	250	099	046	1322697	002857	230	56	455	167	40	46
1071	229	112	034	1324036	002891	266	50	446	166	40	41
1072	259	127	041	1323493	013277	236	52	434	175	33	43
1073	300	122	093	1323239	223115	273	54	527	20[illegible]	35	42
1074	334	115	069	1324155	053184	261	45	442	19[illegible]	29	40
1075	408	127	079	1324273	023492	255	56	470	172	34	40
1081	293	132	036	1325138	403439	243	56	500	16	37	40
1082	347	131	065	1323824	072802	245	50	448	173	39	40
1083	297	121	016	1316095	063279	271	44	480	176	34	41
1084	341	122	051	1324064	033130	256	52	472	194	36	41
1085	348	131	068	1324629	323500	252	59	517	160	37	41
1091	294	129	103	1324078	012857	241	43	419	177	25	40
1092	293	124	120	1323895	022978	252	44	402	171	32	41
1093	337	128	080	1324532	023014	281	50	456	184	36	42
1095	320	119	089	1323727	003316	305	63	502	190	41	44
1101	239	113	015	1325151	013413	290	40	439	168	33	41
1102	371	119	086	1324596	003726	305	62	506	169	50	45
1103	271	105	083	1323540	003109	270	62	472	185	38	42
1104	274	099	076	1323451	163672	270	51	466	193	24	40

Appendix Table 1 continued

1	2	3	4	5 6	7 8	9	10	11	12	13	14
1105	250	101	038	1324100	023372	266	56	473	175	41	40
1111	322	122	038	1324018	183282	297	55	431	159	26	42
1112	298	109	043	1323912	253260	260	46	481	165	31	40
1113	365	133	065	1325275	263066	266	52	472	164	27	41
1114	356	131	038	1324576	063386	279	54	466	155	38	44
1115	350	110	017	1323921	003336	272	55	440	182	34	43
1121	285	099	068	1324346	113529	256	40	392	171	27	42
1122	365	115	048	1324654	273604	314	51	467	169	28	39
1123	242	117	073	1323569	353515	309	55	488	161	35	43
1124	302	096	034	1324680	153497	313	55	484	164	40	39
1125	320	133	099	1324448	083518	312	48	448	187	36	46
1131	340	116	051	1324143	013205	227	40	409	160	26	41
1132	360	146	046	1326250	003309	237	44	370	167	21	43
1133	306	120	033	1324029	003111	231	46	446	165	33	38
1134	327	116	046	1324907	033201	210	50	452	189	30	44
1135	288	116	062	1324082	033440	267	43	397	174	26	39
1141	232	104	039	1323970	243556	239	50	457	156	22	43
1142	274	105	063	1324647	013299	311	45	405	179	31	43
1143	309	114	074	1323722	022881	294	51	471	196	34	41
1144	277	111	107	1323458	123796	293	52	475	155	40	43
1145	322	110	073	1324166	063643	316	61	453	151	42	39
1151	347	104	057	13[illegible]3561	[illegible]03405	313	60	426	149	34	40
1152	355	129	087	1325294	013396	272	52	466	173	35	42
1153	371	119	085	1323752	113568	341	36	431	171	34	44
1154	326	103	063	1324046	403127	296	57	480	172	36	43
1155	312	105	027	1323747	013616	323	47	444	183	34	42
1161	319	111	060	1323758	013533	267	62	495	162	40	40
1162	316	112	099	1324502	003131	321	55	482	173	42	44
1163	279	097	083	1323210	113479	254	46	433	172	32	40
1164	246	099	063	1323196	002556	256	42	426	185	35	45
1165	312	123	090	1324725	033518	305	60	497	175	36	40
1171	298	107	027	1324589	263501	280	58	492	146	35	39
1172	305	097	070	1322621	143353	294	56	507	156	34	40
1173	301	133	071	1325134	403647	306	60	557	175	30	44
1174	347	128	065	1323516	023330	260	48	472	17[illegible]	32	47
1175	268	105	039	1323055	032930	256	49	439	157	39	37
1181	405	125	070	1325628	013606	284	54	437	185	30	43
1182	264	105	054	1324104	023220	290	52	459	184	40	41
1183	255	101	020	1324081	003353	325	61	487	185	41	41
1184	331	126	098	1324942	053202	256	57	431	159	40	39
1185	416	114	093	1324731	063190	254	44	422	175	31	39
1191	315	110	097	1324340	103455	303	52	469	172	33	43
1192	286	121	073	1323633	003480	307	66	504	203	42	40
1193	323	125	062	1325925	233658	294	56	550	157	30	39
1194	304	120	097	1323853	113408	320	61	466	180	40	42
1195	300	112	081	1323631	273101	295	69	540	184	39	38
1201	276	118	127	1325006	003573	263	48	445	185	37	43
1202	348	104	122	1323837	243127	303	52	460	178	36	38
1203	361	128	067	1322705	022796	260	53	473	186	37	39
1204	275	098	075	1323752	022808	253	52	472	156	39	41

Appendix Table 1 continued

1	2	3	4	5 6	7 8	9	10	11	12	13	14
1205	255	104	062	1325428	063374	264	57	535	180	32	40
1211	303	130	037	1325223	033123	267	65	490	168	43	44
1212	359	128	045	1324423	013294	290	55	474	159	34	44
1213	384	130	030	1324128	343202	285	61	523	161	37	40
1215	319	132	019	1224929	023240	279	58	488	181	35	41
1221	324	138	041	1325563	023231	275	56	458	162	33	40
1222	325	136	040	1324522	022876	255	48	439	159	24	38
1223	298	132	032	1323998	013322	276	54	476	176	33	40
1224	328	140	073	1324105	013045	263	43	420	181	33	45
1225	284	117	006	0050130	403157	276	56	534	172	35	40
1231	243	105	006	0922902	303598	272	58	520	155	39	39
1232	268	110	006	0752196	003371	253	55	477	167	38	40
1233	276	120	008	1264211	073261	243	68	475	175	45	43
1234	267	108	030	1324175	073239	284	54	470	184	35	40
1235	311	123	006	0873210	123586	270	46	445	172	23	42
1241	323	123	096	1325969	003060	273	57	481	190	33	39
1242	354	122	108	1323680	103472	278	53	486	168	38	40
1243	347	120	017	1103109	112942	280	69	547	182	51	42
1244	277	099	061	1323115	103315	276	53	459	172	38	42
1245	300	106	042	1323067	002316	251	46	439	165	30	41
1251	370	104	087	1324065	193343	310	56	556	177	30	41
1252	308	111	021	1323134	012492	284	56	484	166	34	40
1253	347	120	077	1325145	293537	319	55	510	152	39	39
1254	277	099	009	0320533	303161	309	60	523	172	25	43
1255	339	119	043	1324607	052728	244	48	484	168	28	44
1261	301	115	057	1325758	342947	277	64	505	181	36	39
1262	366	136	054	1325304	403868	328	64	540	169	36	39
1263	367	115	106	1324699	223236	301	56	536	189	36	40
1264	312	124	026	1325061	003889	281	57	518	177	38	42
1265	309	100	052	1322862	023216	301	50	472	208	29	43
1311	340	135	066	1324924	103478	280	50	459	180	30	41
1312	419	117	024	1325261	123533	270	49	514	181	34	42
1313	320	135	056	1323687	173697	283	59	485	152	29	39
1314	281	109	038	1323911	043545	319	51	457	167	31	38
1315	282	116	048	1322494	102799	283	53	493	171	35	43
1321	291	113	082	1324555	063465	301	58	509	181	41	44
1322	336	104	014	1322957	032519	208	58	487	185	33	41
1323	275	107	024	1324742	023333	269	48	505	176	36	43
1324	293	125	063	1323764	153120	268	64	541	186	38	41
1325	263	098	027	1323958	023179	265	53	501	177	40	40
1331	307	098	038	1322600	022819	261	56	427	184	34	41
1332	298	100	071	1322608	142479	261	55	510	193	34	41
1333	296	099	015	0210536	003059	256	43	409	174	36	42
1334	363	098	068	1323123	023270	266	52	431	176	30	40
1335	305	106	055	1322848	063289	279	47	425	185	31	45
1341	308	107	074	1322924	193477	271	56	492	168	40	40
1342	288	117	064	1323497	013228	250	59	492	170	42	37
1343	283	104	056	1323065	063468	266	63	508	167	47	41
1344	374	115	069	1323399	173157	285	58	479	154	39	40

Appendix Table 1 continued

1	2	3	4	5 6	7 8	9	10	11	12	13	14
1345	292	107	041	1323447	203444	295	63	511	156	36	41
1351	317	124	054	1324094	003082	242	53	467	180	34	40
1352	279	114	047	1324137	003599	306	50	484	174	43	41
1353	299	126	031	1325771	033737	299	48	453	182	37	45
1354	273	101	040	1323990	203612	256	58	491	161	29	41
1355	314	127	044	1324663	013992	267	59	494	162	39	40
1361	287	124	063	1323850	003340	246	50	435	177	30	40
1363	303	130	047	1324551	063509	311	52	473	171	25	38
1364	235	106	032	1322738	222932	235	55	485	167	32	40
1365	306	123	042	1324965	213404	266	44	495	167	29	41
1371	271	123	034	1323693	203028	279	56	476	159	31	39
1372	315	125	077	1323721	003429	266	47	401	146	38	39
1373	257	113	040	1324429	003110	257	48	417	178	30	46
1374	323	120	030	1323915	283226	270	45	426	149	28	38
1375	314	127	039	1324316	272993	276	51	503	166	24	38
1381	284	111	016	1324853	083376	231	56	483	162	39	40
1382	308	116	046	1323755	002806	245	52	461	164	38	41
1383	321	123	060	1324670	103441	242	55	510	170	35	43
1384	226	129	057	1323067	002964	190	54	504	176	39	40
1385	249	093	018	1322288	022790	230	49	442	173	28	46
1391	301	126	075	1325534	373712	309	58	526	165	38	41
1392	358	122	099	1325257	403816	271	72	561	159	35	39
1393	388	130	117	1325404	393656	245	68	541	183	39	41
1394	380	126	091	1325171	393575	276	55	486	163	39	44
1395	400	119	082	1324794	093706	297	60	537	176	40	44
1401	399	135	055	1326333	003717	277	67	506	184	41	38
1402	360	119	037	1325456	393386	245	61	533	184	34	40
1403	364	126	037	1324282	003650	[illegible]	60	465	186	39	42
1404	340	112	039	1324352	163678	261	[illegible]	501	163	36	39
1405	266	117	034	1324615	044040	311	54	457	163	37	39
1521	303	129	070	1324653	003621	314	55	[illegible]	155	35	41
1522	321	128	065	1324797	013686	297	56	[illegible]	189	38	42
1523	303	106	037	1323904	003147	268	50	445	160	37	43
1524	311	116	063	1323484	033532	267	55	469	[illegible]	31	37
1525	245	103	021	1322580	003005	287	50	452	[illegible]	33	46
1541	310	102	048	1324037	133130	316	56	520	186	28	40
1542	239	105	036	1322475	013402	315	58	506	[illegible]	43	40
1543	258	102	031	1322605	013029	293	58	466	173	38	41
1544	292	100	030	1323920	023049	319	57	507	190	30	40
1545	336	108	039	1323532	022981	316	55	519	163	36	41
1551	323	122	058	1324648	003399	286	61	478	167	28	40
1552	343	122	086	1324468	133440	309	62	488	193	43	39
1553	338	116	065	1324883	303182	268	70	551	157	33	40
1554	359	120	051	1324813	023969	296	55	495	169	44	41
1555	337	123	052	1324405	273577	267	58	510	184	31	40
2291	197	081	003	0210521	013145	201	37	385	173	21	42
2292	272	091	010	0671259	013369	253	46	469	157	35	40
2293	275	104	003	0150535	043466	273	51	457	167	41	41

Appendix Table 1 continued

1	2	3	4	5 6	7 8	9	10	11	12	13	14
2294	256	103	014	070 2811	01 3872	279	46	427	171	35	41
2301	276	118	043	1324539	152944	268	53	459	179	27	39
2302	328	136	074	1324545	113256	225	41	411	186	28	39
2303	241	107	016	1324755	383368	261	50	495	163	37	40
2304	299	110	021	1324129	383141	275	56	517	187	33	43
2305	340	119	028	1324720	362893	277	54	464	180	28	43
2411	333	113	072	1323909	293443	293	52	503	172	29	45
2412	314	122	059	1323337	143485	356	61	588	180	47	43
2413	329	117	064	1323507	073391	295	51	473	185	42	41
2414	332	124	088	1323128	033448	287	49	443	176	33	42
2415	330	117	066	1324751	003572	331	46	499	201	30	54
2421	282	137	014	1094282	364268	280	57	504	176	42	41
2422	333	126	055	1323283	093643	283	51	451	165	36	39
2423	330	141	054	1323802	193240	320	61	546	206	39	46
2424	251	112	027	1323558	283821	270	56	510	194	25	39
2425	303	114	016	1324477	053805	276	48	451	192	28	38
2441	322	106	045	1323786	013399	247	44	453	173	35	44
2442	287	097	021	0822118	023746	252	54	464	175	38	40
2443	218	095	028	1323655	053676	194	39	454	188	31	52
2444	309	115	012	1073729	372930	280	54	554	195	29	39
2445	252	103	049	0481460	153363	260	47	468	181	28	46
2451	255	113	010	1142678	043696	237	46	416	183	26	39
2452	260	110	027	1323638	383205	243	48	489	165	24	44
2453	285	122	028	1324618	103933	258	57	523	163	40	40
2454	309	130	054	1324361	253143	268	59	519	200	31	45
2455	259	122	040	1323441	343331	247	55	508	187	39	49
3271	417	130	043	1326377	034059	302	54	476	178	33	38
3272	333	093	032	1324980	033891	291	57	510	184	42	43
3273	367	118	028	1326771	003236	276	52	449	177	40	41
3274	290	101	038	1324050	033254	283	49	446	188	41	43
3275	300	117	036	1323862	153405	258	48	436	195	35	41
3281	362	102	052	1323127	003194	265	43	480	180	32	48
3282	337	121	011	1323881	003965	285	53	502	182	38	42
3283	353	137	059	1325043	154323	330	63	561	166	47	41
3284	330	127	032	1323866	023696	282	50	474	165	33	44
3285	360	125	024	1324140	013690	282	53	484	177	30	44
3431	294	104	036	1324812	053935	280	48	521	180	46	47
3432	303	115	023	1323498	033860	305	55	511	176	34	42
3433	370	121	052	1323912	003453	276	54	501	200	38	48
3434	301	123	043	1324396	102956	233	55	513	189	38	45
3435	301	132	080	1324609	004133	321	53	467	170	35	39
3461	296	130	041	1323663	024237	281	57	527	198	39	42
3462	276	135	028	1324635	003846	343	58	529	180	37	50
3463	309	127	053	1324026	003646	281	55	516	179	41	54
3464	403	137	056	1325066	004611	345	50	505	194	35	45
3465	305	130	031	1324818	004355	278	55	506	174	44	45
3471	223	102	014	1322641	063658	197	42	420	164	27	45
3472	252	100	007	0991969	014383	195	49	381	158	30	37

Appendix Table 1 continued

1	2	3	4	5 6	7 8	9	10	11	12	13	14
3473	285	109	006	0531084	003550	223	51	471	155	27	43
3474	275	114	010	0932261	003328	194	39	432	147	24	51
3475	227	119	013	0721605	033721	204	51	481	182	31	47
3484	201	110	018	1323420	003667	255	56	526	173	41	51
3485	293	114	035	1324227	013649	239	58	494	175	37	50
3491	246	092	010	1324029	033954	319	56	454	166	39	43
3492	268	105	064	1323770	003693	332	46	509	185	37	58
3493	295	116	029	1325009	033935	341	60	526	184	36	44
3494	262	106	038	1323332	003662	335	58	491	180	35	41
3495	300	100	074	1322927	053602	328	50	509	192	35	55
3501	366	115	056	1324940	013694	288	46	444	195	43	43
3502	251	119	077	1324140	003471	300	49	457	165	43	45
3503	289	107	056	1323396	162640	273	52	489	182	22	48
3504	344	109	071	1323364	034277	332	60	491	167	43	47
3505	270	105	057	1323507	023104	285	57	548	183	31	54
3531	193	075	002	0140134	013323	169	51	498	157	34	51
3532	215	102	006	1011331	073381	221	44	479	184	31	47
3533	244	098	002	0190301	004274	275	60	545	189	42	48
3534	207	102	001	0170284	003106	211	52	533	176	39	47
3535	210	083	005	0720778	003148	195	53	519	190	29	44

KEY TO APPENDIX TABLE 2

Column no.	Item
1	Seedling identification. The first digit indicates group number; the second and third, stand number; the fourth, mother tree number; and the fifth, seedling number.
2	Total height of seedling--centimeters.
3	Stem diameter of seedling--millimeters.
4	Data not pertinent to the study.
5	Number of ternate fascicles in a sample of 10 fascicles.
6	Sum of the lengths of three fascicles--millimeters.
7	Sum of the lengths of three fascicle sheaths--millimeters.
8	Sum of the numbers of rows of stomata on the flat surface (or surfaces) of two needles.
9	Sum of the flat surface widths of two needles--micrometer units. (100 micrometer units = 1.68 mm.) $\frac{\text{Col. 8}}{\text{Col. 9}} \times \frac{1}{.0168} =$ number of rows of stomata per mm. of needle width.
10	Sum of the numbers of stomata counted in four stomatal rows, each 1.68 mm. long. These values, divided by 6.72 give numbers of stomata per mm. Also, $\frac{\text{Col. 8} \times \text{Col. 10}}{\text{Col. 9}} \times \frac{1}{.04(1.68^2)} =$ number of stomata per sq. mm.
11	Sum of the numbers of resin ducts counted in each of two needles.
12	Sum of the numbers of hypoderm layers counted at four points in each of two needles. These values, divided by 8, give average numbers of layers of hypoderm per needle.

Appendix Table 2.--Progeny data of Nursery Test 1

1	2	3 4	5	6	7	8	9	10	11	12
10111	24	08085502700549	05	422	30	14	142	63	05	11
10112	25	06084501900384	07	414	19	14	152	64	05	10
10113	23	07072001700429	10	414	18	15	152	58	04	08
10114	24	07110003250649	10	503	20	14	148	72	04	09
10115	29	08074502800674	03	445	25	12	133	64	00	11
10121	21	06045001550323	09	430	30	13	143	71	05	10
10122	21	07059501900348	03	411	26	09	123	65	04	11
10123	30	08071503250583	10	464	17	12	133	66	04	12
10124	29	06076001800298	08	413	21	13	130	66	04	10
10125	31	06122501900368	09	345	22	15	145	67	04	12
10131	18	06059501700390	10	307	17	15	147	54	04	13
10132	28	07077902100424	07	460	28	17	172	59	05	11
10133	21	06057501590374	10	530	23	18	164	60	06	10
10134	23	07102002500543	08	462	23	15	166	60	04	15
10135	33	08155904210779	10	514	21	14	173	60	05	14
10141	34	08076003200597	08	387	23	14	165	62	05	11
10142	25	07068501750482	10	372	20	18	171	69	06	14
10143	26	07105503350612	08	399	24	16	161	61	04	15
10144	25	06064001800527	09	419	21	15	149	63	04	11
10145	19	06094001200332	05	426	20	12	147	66	05	11
10151	36	09153405280794	10	536	22	13	166	70	04	11
10152	20	05032501000169	09	412	18	13	145	65	04	12
10153	32	07078702700584	09	381	25	14	149	59	04	11
10154	33	07068602930548	10	416	28	14	146	63	04	11
10155	36	10105405341141	10	531	22	15	162	63	05	14
10211	19	07066001700372	06	374	20	16	148	70	05	13
10212	19	06058001230307	07	417	20	13	136	64	04	09
10213	26	07062502000447	10	456	21	13	138	64	04	11
10214	26	07079702900597	10	439	27	16	170	65	05	14
10215	18	06066302000299	07	462	18	13	144	71	06	10
10221	30	08042002500503	08	440	25	17	161	59	06	16
10222	23	09105203450783	06	441	26	16	142	58	04	13
10223	28	09094004350550	10	573	19	17	169	52	05	12
10224	25	06066002100426	08	429	24	17	156	60	05	11
10225	25	06076701800463	06	389	23	13	142	66	04	09
10231	26	09086002930587	10	497	22	15	142	48	04	08
10232	24	06051101700350	10	418	20	18	160	60	04	09
10233	24	07031202100575	07	388	22	17	168	59	05	10
10234	30	08102505331169	10	517	23	14	152	56	04	14
10235	34	07124002500632	10	412	23	17	156	65	04	13
10241	26	06075402100535	10	421	20	15	152	68	06	08
10242	20	07075501900522	06	470	31	13	151	54	05	12
10243	22	05038001180293	09	440	20	13	148	60	06	09
10244	23	06080002050453	10	585	25	16	148	62	05	10
10245	29	06068501800297	10	354	24	13	147	56	04	08
10251	31	08114003360663	06	425	29	14	142	72	04	13

Appendix Table 2 continued

1	2	3 4	5	6	7	8	9	10	11	12
10252	22	06045601500372	10	390	19	13	139	62	04	11
10253	17	05052400900223	09	361	15	12	149	61	04	13
10254	34	07077203150635	10	425	26	15	166	61	06	13
10255	37	08138305401079	10	435	30	17	170	59	06	13
10311	22	08092403300656	09	454	19	15	162	67	04	09
10312	24	07063001630406	04	426	18	15	140	58	04	12
10313	24	09095402350561	10	400	19	17	167	61	04	12
10314	29	07085003500695	10	423	26	18	164	64	05	12
10315	25	07123603880643	07	540	27	16	170	56	06	12
10321	23	06067102000502	10	426	30	15	170	56	06	16
10322	25	06045001800352	05	390	20	15	158	60	04	16
10323	27	07077202330434	10	389	30	16	166	64	04	16
10324	30	07080402600542	08	387	32	18	160	69	05	16
10325	28	09103503400582	06	396	31	16	155	63	04	10
10331	23	08091402780557	10	448	21	15	154	57	04	13
10332	20	06034901200275	09	407	23	18	166	59	05	12
10333	22	07067902980670	10	444	25	18	156	63	04	12
10334	37	08117003470526	10	495	30	16	162	58	04	11
10335	32	07097003009500	10	360	30	19	173	60	06	13
10341	30	07072302230426	07	410	21	18	167	62	04	10
10342	27	07066502500406	07	356	21	14	148	60	04	10
10343	35	08098704460769	08	461	20	16	175	67	05	15
10344	23	08070002950461	09	557	22	16	142	59	05	09
10345	33	09130005650790	07	487	21	14	151	65	05	14
10351	26	06049502150508	09	379	19	15	146	60	06	09
10352	23	06072001900473	08	405	24	18	153	58	05	13
10353	32	07076002660385	10	416	22	17	162	63	06	11
10354	27	07079102970568	10	419	19	15	164	59	06	14
10355	24	07095502150502	09	398	16	15	159	65	05	14
10411	25	08072002600584	10	445	30	17	142	54	06	12
10412	22	06075501950324	09	487	25	15	148	66	04	13
10413	31	09087504650889	08	462	23	18	165	55	05	15
10414	32	07097502400364	09	470	27	22	160	67	05	16
10415	35	07123503350649	09	488	27	18	174	67	05	14
10421	30	08077103200604	10	430	27	16	146	58	04	11
10422	23	07070801850413	00	479	17	12	130	56	04	14
10423	27	08092803610769	04	479	25	16	157	61	05	14
10424	23	08096004391018	10	551	30	17	157	65	06	16
10425	25	09209805891432	08	534	22	15	153	59	06	12
10431	23	07094202400676	10	543	26	18	176	64	06	12
10432	19	06054001600322	04	428	17	15	158	66	04	09
10433	27	06057002300549	10	471	23	17	166	61	04	13
10434	30	06090502670617	08	512	20	17	150	66	06	08
10435	21	08093803150603	01	461	21	13	133	57	04	10
10441	23	07082603020597	10	455	22	15	144	55	04	15
10442	29	07054001730346	09	446	27	17	164	52	05	11
10443	23	07075002420527	09	465	23	17	152	63	06	11
10444	19	07069202250419	10	440	18	14	154	63	05	13
10445	26	09125005101034	10	499	20	15	159	52	06	12
10451	17	06030800900156	09	459	20	13	162	65	05	11
10452	19	06049001490256	06	504	30	14	157	55	06	09

Appendix Table 2 continued

1	2	3 4	5	6	7	8	9	10	11	12
10453	21	06045001400317	10	368	17	14	145	58	05	09
10454	20	06056001020250	09	392	25	18	168	65	06	10
10455	30	08162005400939	10	524	25	21	170	67	05	14
10511	27	07069002400454	10	353	21	17	173	63	06	13
10512	21	05063201610263	08	322	14	20	177	59	04	09
10513	25	05082901280323	10	323	18	16	170	65	06	10
10514	26	07083002250563	10	454	21	14	153	61	05	13
10515	30	06041801200214	10	300	21	16	150	68	06	12
10521	35	08108605100741	10	491	21	18	157	51	04	12
10522	23	07071002440520	08	400	21	14	126	61	04	13
10523	31	08120004180575	09	527	19	15	167	59	04	12
10524	30	07053202500470	10	498	24	15	151	58	04	11
10525	50	11142205900923	10	479	25	18	166	57	04	14
10531	31	08099003990812	10	416	21	16	153	56	04	12
10532	21	07063702010398	07	373	20	14	155	53	07	15
10533	29	07064302850434	08	386	30	12	132	66	05	13
10534	23	08075202440474	08	527	21	13	160	52	04	14
10535	43	08103605390808	10	469	25	19	177	57	05	14
10541	28	06074802480573	07	549	23	15	151	59	07	10
10542	23	07055502250464	09	436	23	16	168	64	06	14
10543	20	06048701180173	09	382	21	12	139	66	04	15
10544	21	06070301630331	09	381	16	16	148	60	06	16
10545	30	05051801590288	10	389	24	17	151	58	05	13
10551	29	08090503800659	08	367	24	13	155	59	04	11
10552	25	08081002800549	09	407	24	16	155	66	04	15
10553	28	08086104290743	10	446	21	17	175	60	05	15
10554	29	07075102850590	10	485	19	15	156	63	05	11
10555	25	08089204000679	10	425	19	16	170	60	05	13
10611	33	08144004350935	09	534	23	18	167	63	06	09
10612	32	07061302060409	08	453	21	11	134	59	05	10
10613	26	06055002000360	10	493	17	12	158	55	04	13
10614	27	07084003650390	10	425	15	12	147	59	04	09
10615	20	07083002130499	10	424	13	12	137	61	04	13
10621	35	08109005270786	10	441	21	16	155	56	05	14
10622	23	07060001780353	10	516	20	20	181	62	05	13
10623	24	07061502000367	10	428	20	19	176	65	05	12
10624	25	06038801400271	09	388	17	16	154	63	05	10
10625	33	08164004900920	06	507	18	12	128	62	04	08
10631	21	07060001900455	10	397	18	11	151	63	05	10
10632	20	05063901300410	10	415	23	13	156	63	04	10
10633	34	10127008651245	10	533	20	15	158	68	06	10
10634	32	06083002580567	10	459	13	15	153	64	06	09
10635	14	04032500500135	09	364	22	11	143	62	05	13
10641	23	07063502400480	10	350	17	15	160	64	05	12
10642	19	06045501700325	07	432	17	14	165	62	05	11
10643	32	07076503450665	10	482	15	14	165	64	05	09
10644	21	07055001900450	10	449	21	14	155	64	04	08
10645	38	10130507651245	10	545	22	18	176	60	06	08
10651	27	07061102000605	09	378	19	16	162	65	05	15
10652	21	05043901020245	07	397	14	16	165	57	05	14
10653	26	05050101830394	10	346	16	15	157	61	06	13

Appendix Table 2 continued

1	2	3 4	5	6	7	8	9	10	11	12
10654	14	05025800680137	10	521	18	16	160	61	05	13
10655	32	07088403350321	09	444	23	17	166	53	06	11
10711	27	08113003320572	09	411	18	16	158	57	04	13
10712	21	07066102100387	05	357	22	16	144	53	04	15
10713	24	07134002730501	06	430	21	11	127	59	04	12
10715	25	08088501770335	09	419	33	16	156	60	05	12
10721	28	10132304600780	10	412	22	19	155	69	04	13
10722	28	09098703300783	06	456	21	19	152	68	04	12
10723	26	07103503000603	10	455	22	16	168	70	04	12
10724	24	07067602800524	09	482	22	13	148	51	04	14
10725	34	09125706031030	10	473	19	15	155	70	04	15
10731	29	08104403300842	10	394	22	17	177	66	06	15
10732	22	05037200680199	10	405	29	14	150	63	05	12
10733	19	04050300620222	10	423	22	15	161	60	06	12
10734	32	08115002200618	09	420	25	14	158	65	04	16
10735	35	08107203010769	10	503	27	18	162	61	06	09
10741	32	07088003920824	08	389	19	17	161	67	04	10
10742	18	06065001880376	09	418	17	14	129	61	04	12
10743	20	06109902050419	10	424	20	14	149	66	04	10
10744	26	09079403850802	04	496	26	14	142	69	04	12
10745	20	06094801900377	08	364	18	14	150	64	04	10
10751	30	07044502500413	09	432	24	12	150	66	06	12
10752	27	08074002400503	07	428	24	18	156	54	08	10
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10824	36	08083003580619	10	421	21	13	142	62	04	15
10825	38	08113803300646	10	389	20	12	148	52	04	14
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10832	20	07104502910588	09	437	23	14	165	64	04	11
10833	28	0807650358[illegible]581	10	470	21	12	163	65	04	11
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10835	24	08100502310511	08	437	19	13	155	61	04	13
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10844	31	09145503400799	10	526	22	14	155	53	05	11
10845	33	09116204590980	08	490	28	20	167	63	05	10
10851	25	07091202900711	10	443	16	16	162	63	04	10
10852	23	07052502110470	10	230	22	18	182	60	06	14
10853	33	08144004851101	07	548	23	17	161	58	04	11
10854	25	07085002400591	10	458	21	20	155	54	06	08
10855	31	07156203120679	09	489	19	17	161	54	06	12

Appendix Table 2 continued

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10913	30	09123204060746	10	472	32	15	171	63	05	12
10914	20	06048801080243	10	397	31	14	159	66	04	11
10915	37	11170707120942	10	429	27	17	166	57	06	13
10921	18	05028500800120	09	424	33	13	158	64	06	09
10922	23	08071402880463	10	430	18	16	168	63	04	12
10923	26	08071602800609	10	412	25	14	155	60	04	10
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10925	26	11107404080857	09	480	24	15	167	64	06	15
10931	25	09096404010864	10	453	19	15	144	56	04	13
10932	24	06069001790300	05	347	25	11	152	64	04	12
10933	32	07051802520613	05	417	23	14	156	63	04	08
10935	23	06072002660472	10	416	28	12	151	54	04	10
10941	29	08079003870598	10	364	19	13	144	61	04	13
10942	14	04022100500121	08	424	24	15	164	63	04	13
10943	27	06053301750356	10	444	24	15	148	70	04	10
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10945	33	09111304260896	10	540	29	17	182	64	06	16
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10953	34	09091905300842	10	547	23	22	177	62	06	12
10954	26	07079903100535	09	518	36	20	176	64	05	15
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11011	30	09102803610782	08	473	30	14	153	58	04	14
11012	25	06058701850430	09	403	17	12	152	60	04	11
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11025	39	08100903820680	09	432	25	18	181	59	06	14
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11034	23	07063102310456	06	429	21	16	158	57	04	13
11035	29	09124004600825	10	456	27	14	156	54	04	12
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11042	17	06031400890197	06	442	26	13	145	68	04	10
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11044	25	08074403710691	09	482	24	16	175	62	05	12
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11052	25	06028101310178	08	348	19	12	130	67	04	15
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11112	22	06049702240318	09	364	25	15	144	50	04	11
11113	21	07048003150510	10	425	21	14	155	51	05	10
11114	20	06041201620230	10	470	22	16	157	60	05	11

Appendix Table 2 continued

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11122	19	06	045601120254	10	408	19	11	142	62	05	09
11123	20	07	056602300507	09	423	24	14	145	59	04	10
11124	24	07	078502280552	09	488	20	12	154	53	04	10
11125	30	10	120003720712	10	462	26	16	160	59	06	09
11131	31	07	067003200658	06	342	19	14	156	58	05	09
11132	23	07	055002070335	10	408	25	18	174	57	06	09
11133	26	08	108204700985	09	472	22	13	140	58	05	14
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11135	47	11	120108041219	10	395	19	13	168	57	06	16
11141	31	08	069504510738	09	282	15	14	162	55	04	13
11142	29	07	052002300461	09	337	13	09	130	65	04	13
11143	36	07	085003450644	03	425	22	13	146	63	04	16
11144	27	07	067503350476	04	404	16	10	145	61	04	13
11145	39	07	084004220867	07	442	20	12	151	53	04	15
11151	23	07	076002650483	10	425	19	14	160	62	05	12
11152	26	06	080902790393	02	394	18	14	146	63	05	14
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11154	20	05	039001190269	07	476	25	16	149	57	04	14
11155	17	04	013000450124	06	433	24	12	136	66	04	12
11211	24	06	085002390587	10	379	26	18	158	59	04	15
11212	24	06	063701480361	10	445	23	16	159	58	05	13
11213	26	08	092403470639	10	586	24	17	163	53	06	11
11214	10	05	033000420196	09	426	23	16	161	57	06	11
11215	28	09	104804130859	10	407	21	16	158	56	05	13
11221	29	08	074603050680	10	384	23	18	164	69	06	11
11222	20	06	050401130295	05	478	24	16	138	59	05	13
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11225	26	08	107802970472	10	516	21	14	151	59	04	08
11231	19	07	046001500311	10	389	25	16	163	61	05	10
11232	21	06	064001920391	08	408	23	17	155	61	04	15
11233	30	07	060903000530	10	386	26	16	162	62	04	15
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11242	17	06	037001280145	09	458	25	16	175	60	06	14
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11244	28	08	076503170688	03	432	22	12	134	59	04	13
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11255	23	06	075004620587	10	343	20	14	144	59	04	13
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11312	26	06	056001900457	05	398	22	14	144	62	04	13
11313	24	07	071802700378	09	509	18	17	157	62	04	10
11314	21	07	123502350524	10	420	24	14	168	61	05	12
11315	21	08	085503300675	09	479	19	13	154	57	05	11
11321	38	09	123005760873	10	349	24	16	163	62	05	14

Appendix Table 2 continued

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11324	21	08098702700582	06	413	20	11	129	82	04	14
11325	26	09136804110719	10	464	19	15	160	65	04	16
11331	31	09087704320792	09	444	21	18	166	54	04	14
11332	21	07075501920443	09	448	26	16	158	62	06	14
11333	20	07056802040394	10	474	27	14	163	56	04	16
11334	26	07125002540598	07	510	26	15	157	58	05	14
11335	18	06066601520373	08	406	15	14	151	60	04	11
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11342	22	07078302300413	10	436	21	18	148	52	08	14
11343	24	05051201180208	09	362	25	13	142	62	06	12
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11345	36	08124006001132	09	494	25	16	161	70	05	16
11351	23	07086202450527	09	490	25	20	156	58	05	16
11352	21	07064701550394	10	383	21	20	166	58	06	16
11353	30	07080403570580	07	505	26	20	178	61	05	16
11354	22	08057702020328	04	409	25	19	155	53	06	12
11355	29	08124504140774	10	409	21	17	169	65	05	12
11411	38	09117506290914	10	400	23	12	165	60	05	14
11412	23	05061101550316	10	458	24	14	143	59	04	15
11413	28	07045102610510	10	364	18	14	164	57	05	14
11414	23	06059201610361	08	428	24	14	150	56	04	11
11415	38	08093803310715	10	397	21	15	166	68	04	16
11421	23	08076002930486	06	421	31	14	159	57	05	08
11422	24	06094202100470	10	444	24	14	150	57	06	09
11423	29	07114403100751	10	482	23	15	159	58	04	15
11424	27	08076002870536	06	473	27	16	154	64	05	11
11425	29	08154604350983	03	524	26	18	168	62	05	15
11431	25	06062001850573	10	397	25	15	164	61	06	12
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11454	30	07090403300699	10	509	27	18	157	59	05	13
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11511	23	09063202400432	10	437	21	14	142	51	04	15
11512	21	09080902390538	10	457	26	16	151	57	05	15
11513	20	07072402050500	08	457	21	13	149	72	04	13
11514	22	07092502900529	10	511	24	22	183	59	06	14
11515	27	08133403800883	10	468	19	18	163	53	05	12
11521	34	07068803350789	10	443	23	16	165	63	04	12
11522	25	07079901770343	06	432	25	17	171	56	04	08
11523	39	08077605360888	10	458	23	17	184	63	06	15
11524	26	09114804560717	10	485	22	13	153	57	04	13

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11532	24	07062902020380	09	400	19	15	165	56	06	10
11533	28	08074903390680	10	514	36	17	183	60	06	12
11534	30	07081003090563	07	491	22	16	171	57	05	16
11535	25	05062301030217	09	348	25	12	146	56	04	15
11541	34	09075004130627	10	412	23	16	151	60	05	15
11542	21	06043401300236	09	382	20	12	144	57	04	16
11543	21	06075501700360	10	342	21	14	137	58	04	15
11544	32	07011502400503	10	433	21	16	154	55	04	15
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11552	25	10091403350579	10	512	28	14	150	51	05	13
11553	25	07077002430403	10	458	20	16	155	63	04	13
11554	20	06081402030361	08	483	23	14	169	65	05	09
11555	28	07129002560647	10	399	23	13	158	70	05	12
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11614	30	07109304201052	10	586	39	20	159	58	06	11
11615	38	10132505401092	10	519	28	16	164	57	05	11
11621	32	07066704320719	09	433	32	18	154	57	05	12
11622	28	07056603100434	10	356	23	19	167	66	05	12
11623	23	07094202460548	09	505	28	17	161	60	06	13
11624	20	07059702450511	06	475	28	19	178	70	06	13
11625	40	09125606651206	10	450	28	17	188	56	06	13
11631	27	08082903050594	10	384	30	15	157	63	04	11
11632	22	08093003350758	10	444	27	10	149	56	05	13
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11645	30	09160403320728	07	499	22	14	147	61	04	15
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11713	26	05061501380423	07	496	28	11	145	55	04	12
11714	27	06061001990531	10	508	27	14	157	55	05	15
11715	43	08126205981192	06	581	25	14	154	52	04	12
11721	20	06064801330492	09	505	29	14	148	69	07	11
11722	18	05036400820241	08	520	24	14	158	63	05	13
11723	17	06067301700442	08	522	22	13	155	58	05	11
11724	12	05043600700261	09	422	25	16	167	65	04	13
11725	28	07071602200666	09	572	24	15	150	60	04	13
11731	22	07079202150611	10	512	24	14	156	60	05	11
11732	18	07065001820461	10	590	26	12	145	67	04	10

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11735	27	07091003470789	10	565	26	16	163	55	05	11
11741	23	07103302390555	07	500	24	14	125	68	04	10
11742	25	07049901600358	08	437	21	13	135	66	05	10
11743	20	05064101400455	08	495	23	11	121	58	04	12
11744	23	06060901490472	08	598	27	16	164	55	04	12
11745	23	07089201430435	10	439	25	14	150	60	04	11
11751	34	08076002800571	09	462	27	16	136	55	04	11
11752	28	05051701220327	10	437	35	17	138	58	04	11
11753	25	07053302460515	10	431	34	14	141	57	04	09
11754	20	07116403580895	10	496	28	16	158	56	04	10
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11812	22	06072501300494	09	506	26	11	128	63	04	11
11813	25	07083703290656	10	462	22	14	153	62	06	15
11814	33	07080002810810	09	448	27	13	142	56	05	14
11815	28	06089001690542	06	379	30	16	155	58	06	12
11821	26	07067002450647	10	425	22	17	159	56	06	13
11822	24	06048001860396	10	408	24	15	164	57	04	10
11823	25	06062702410492	06	508	28	13	138	65	04	15
11824	30	06063202700713	10	416	28	15	187	64	04	13
11825	34	08094304300778	10	495	31	14	163	56	04	12
11831	33	06067502600558	10	396	25	21	158	68	04	13
11832	24	06067002000514	10	393	24	14	151	63	04	11
11833	34	07089503820934	10	546	26	16	143	58	04	16
11834	35	08096502890808	09	490	30	18	179	58	06	16
11835	23	07095102800686	10	500	28	16	165	65	05	16
11841	31	09136005720869	10	451	23	18	171	57	06	15
11842	26	06049601400349	10	469	25	18	161	50	05	15
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11844	24	08113503550578	10	545	35	21	196	65	06	15
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11851	31	08084903480774	10	450	28	15	155	64	06	12
11852	21	06053601510422	10	348	25	16	163	59	06	12
11853	35	08102003820984	10	559	24	15	144	63	05	13
11854	28	07084902400424	09	396	22	14	145	58	05	14
11855	29	07108003390847	09	515	29	16	154	61	06	14
11911	36	09085003600724	08	515	25	20	155	63	06	16
11912	24	05037201210296	10	476	20	20	181	57	05	15
11913	37	08134604781089	10	523	22	14	157	61	04	13
11914	24	08084402480557	10	544	22	19	170	60	04	11
11915	54	09109207121465	10	530	28	20	183	66	06	15
11921	30	07063202650586	10	447	23	17	160	62	04	14
11922	20	06039201090346	09	385	21	11	117	64	04	09
11923	32	07054202730520	08	430	26	17	159	67	06	15
11924	28	08095503050753	09	390	21	17	182	67	07	16
11925	28	07063802510519	07	468	22	16	162	64	05	15
11931	28	07080003600872	09	355	25	13	153	65	06	15
11932	25	06058101810471	09	435	25	13	157	59	04	09
11933	24	07101802950812	10	473	27	17	171	56	06	16
11934	33	06047801550394	10	585	31	20	178	56	06	13
11935	30	07117202890850	10	547	30	19	181	62	06	13

Appendix Table 2 continued

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11942	26	07089002120595	10	444	27	15	158	63	05	13
11943	25	07057102800622	10	474	21	16	158	53	04	14
11944	27	07062202150633	10	499	26	17	169	62	04	09
11945	27	07085903090690	10	430	29	18	159	60	06	09
11951	25	08080602700676	10	510	26	18	168	54	05	13
11952	31	07083702900625	10	489	28	15	142	67	04	08
11953	26	09108304620970	10	479	26	14	156	63	04	13
11954	25	08071103100693	10	522	25	16	171	56	06	11
11955	25	08134903721182	09	438	25	16	141	69	05	13
12011	30	07068803040596	10	479	25	14	140	53	04	09
12012	22	06069002090411	10	413	22	12	133	64	04	09
12013	34	08074103820668	07	477	25	14	173	68	05	15
12014	29	08081403330810	09	490	19	16	178	58	04	13
12015	30	09108004250804	10	491	24	20	168	57	04	10
12021	30	07066502980490	09	444	24	18	151	67	05	11
12022	25	08097503110566	10	412	20	15	159	64	04	13
12023	20	05033001000150	09	423	19	17	164	56	05	13
12024	33	08074303940716	10	497	23	19	179	58	05	14
12025	35	07079803200530	10	459	23	14	153	56	04	10
12031	34	07076003200574	10	354	24	14	151	57	04	12
12032	20	07047001840376	08	421	21	14	147	58	04	08
12033	40	06052403200567	10	455	30	14	157	56	05	13
12034	27	07072003340446	10	525	23	13	150	49	05	10
12035	33	07102203450592	10	385	24	19	185	56	04	12
12041	23	07072502540587	10	400	23	14	145	61	06	14
12042	21	05063901600269	10	400	22	19	169	54	04	12
12043	26	07073002710474	10	458	25	17	171	55	06	11
12044	24	07105002900630	10	494	25	16	166	56	05	11
12045	26	07110903300560	09	455	27	16	163	63	05	12
12051	23	08050201500162	06	546	20	16	138	56	04	14
12052	23	08080502700495	10	401	18	14	134	51	04	09
12053	27	07061502910539	08	441	22	16	157	69	05	10
12054	28	07069002300415	08	398	23	16	176	62	04	10
12055	37	07081003950645	10	406	26	19	190	62	06	15
12111	27	07032003500605	08	347	21	13	125	55	04	11
12112	25	06038401580243	10	457	25	18	169	57	06	12
12113	27	08073704900319	07	449	24	14	154	55	06	13
12114	36	07081003500652	08	534	26	18	169	49	06	11
12115	33	09096805030984	10	493	29	18	170	54	06	13
12121	37	09093503470630	09	433	20	19	163	55	05	14
12122	30	07065502420452	10	401	18	14	134	62	05	11
12123	31	08073502730507	09	508	23	16	163	70	04	16
12124	25	08087202940573	06	487	22	20	170	61	05	14
12125	27	08140004300937	10	487	28	17	181	51	05	11
12131	28	08100604690731	09	413	19	18	157	71	05	10
12132	25	07073902740436	10	470	25	17	163	58	04	12
12133	31	08120605080842	10	530	25	19	172	60	06	15
12134	29	09103005380702	10	494	22	16	169	56	06	15
12135	46	12186512651789	10	548	30	19	172	56	05	15
12151	38	07058503340505	03	553	28	18	127	47	05	09

Appendix Table 2 continued

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12153	27	08069803770628	10	422	26	18	172	65	06	08
12154	29	07091103720717	10	560	26	16	183	63	06	13
12155	28	07095003150672	10	472	22	18	188	66	06	14
12211	32	07071203310650	10	408	30	16	177	60	06	11
12212	25	06054502010474	06	464	24	12	137	65	04	14
12213	33	08106203960880	06	476	20	13	135	56	05	12
12214	23	06072202620765	10	470	19	14	164	53	04	13
12215	36	08096104410974	09	484	20	14	149	59	06	14
12221	28	07072902890622	08	411	25	15	159	64	05	13
12222	24	08097102900601	10	528	27	14	141	57	05	11
12223	26	09101805190928	10	541	23	21	180	54	04	13
12224	24	07072402310447	10	545	25	14	172	63	05	11
12225	31	09099204090799	10	446	29	19	170	57	06	11
12231	26	07072502500555	10	296	28	16	159	64	06	13
12232	21	08081002500495	10	428	22	13	166	53	06	09
12233	33	06065002700555	10	454	26	13	159	54	06	10
12234	30	08089004750820	07	535	27	15	167	57	05	08
12235	28	10143005150940	10	471	20	18	166	69	06	12
12241	22	07095402820517	09	413	20	14	149	62	04	11
12242	24	06062801820386	10	403	20	13	165	59	05	15
12243	30	08087103740578	07	401	24	22	168	57	05	12
12244	18	05056301120381	09	335	26	14	159	64	05	12
12245	20	07079801240341	10	361	26	13	163	57	05	13
12311	22	06074001650452	09	397	21	14	153	65	05	09
12312	22	06061201810402	08	362	23	14	140	67	04	11
12313	19	09061901550437	06	442	18	14	157	65	04	14
12314	26	08108904600714	10	467	22	14	157	55	06	09
12315	27	07078002200494	10	396	22	17	178	55	06	11
12321	21	07078501900454	09	415	26	17	171	60	06	13
12322	20	07069102200578	10	455	22	14	159	52	05	10
12323	23	07068602970727	10	567	29	15	179	55	05	12
12324	21	07092002350578	10	539	26	13	167	55	05	12
12325	22	07113702600629	10	462	26	14	170	55	05	11
12331	29	09072002850523	09	457	26	21	188	59	06	14
12332	20	07055001900418	07	442	25	19	176	60	06	13
12333	28	07103003200878	09	502	22	20	167	62	04	11
12334	26	06087502950638	10	503	27	20	173	52	06	15
12335	28	07118503000398	10	383	21	16	179	64	06	12
12341	19	06054501460332	10	488	22	14	151	52	04	09
12342	28	07087302940463	08	375	31	16	148	63	04	14
12343	30	09106504840953	09	530	22	16	161	55	06	08
12344	30	07090003600740	07	531	24	14	142	64	04	09
12345	37	10112602900527	01	379	25	15	136	59	04	15
12351	32	09106405901149	10	527	29	16	143	58	05	13
12352	22	06079001900501	10	489	20	15	145	53	04	10
12353	21	06056001400297	10	362	18	10	123	63	04	10

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12354	30	09135005400983	09	506	20	16	142	56	07	13
12355	26	07085202500592	10	454	32	14	165	60	06	12
12411	27	08080002620594	08	480	31	19	164	58	04	10
12412	23	06046801650362	10	480	24	12	139	63	04	09
12413	32	08089103950801	10	560	23	18	165	44	06	11
12414	21	07083502700674	10	470	24	16	179	56	05	11
12415	35	08116904250820	05	448	21	16	189	67	04	14
12421	18	07070002210493	10	395	25	15	150	66	04	10
12422	20	06061201920461	09	476	19	19	164	56	04	08
12423	33	07085003480742	10	474	26	14	149	64	06	11
12424	22	07096202700689	09	479	24	12	148	52	04	10
12425	24	08144202800734	10	429	25	11	153	59	06	10
12431	32	07084002820635	10	410	34	20	180	67	06	14
12432	21	06069002000408	10	392	22	18	166	59	06	08
12433	31	06064103100663	09	443	24	16	164	57	05	11
12434	23	09071001900437	08	511	26	13	150	61	05	13
12435	42	09116205050763	10	469	25	18	192	54	06	16
12441	21	06071502510693	09	484	20	16	159	81	04	09
12442	17	07057501600458	08	433	21	16	143	64	04	11
12443	32	06073003500538	09	528	24	20	163	65	06	13
12444	27	07102902050659	09	486	23	16	162	54	05	15
12445	33	06128505301171	10	556	20	16	151	57	04	11
12451	24	06080001900635	10	382	21	17	164	57	05	15
12452	16	06042301030223	09	503	25	13	136	57	04	10
12453	28	07079603020711	10	503	27	16	153	61	04	12
12454	23	06063001800453	10	461	29	17	160	60	04	13
12455	22	06066502000440	10	418	28	17	160	56	04	11
12511	35	07065003300612	10	464	23	15	153	74	04	15
12512	25	05054901300254	04	452	23	13	134	59	05	13
12513	27	06081002400446	09	487	20	13	166	58	07	16
12514	27	08095502900524	10	527	22	15	164	51	06	14
12515	17	03016000390109	07	330	29	12	121	60	04	10
12521	20	07050001600365	09	370	29	15	145	59	04	14
12522	27	06054001600245	10	522	28	15	143	58	05	11
12523	26	07091103220605	10	577	33	14	158	59	04	14
12524	22	06069202300550	10	455	20	16	156	66	06	15
12525	15	06052300930226	09	345	20	14	140	63	05	14
12531	23	06054701930482	10	440	27	19	143	46	06	13
12532	29	08073003240602	05	527	25	16	144	55	04	12
12533	29	09098606201033	10	556	25	15	157	61	04	13
12534	25	08109802700668	09	562	23	14	151	66	05	15
12535	29	07081503020662	09	567	27	18	159	58	05	15
12541	29	07061502850516	08	343	21	20	166	68	06	14
12542	20	07059901990388	07	497	21	14	145	67	04	15
12543	26	07078502790623	10	437	20	15	155	64	05	14
12544	27	07043802040362	10	408	27	16	153	56	05	15
12545	21	06053201390374	02	453	35	18	145	63	04	16
12551	23	07084703260642	10	410	21	18	157	58	05	16
12552	22	07066302250501	08	369	22	12	146	60	05	14
12553	28	07074003420658	04	494	25	18	155	55	06	15

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12555	31	09186005151175	10	496	34	21	186	54	06	16
12611	32	07077002950685	10	551	29	17	150	58	06	14
12612	31	03078002650525	01	551	17	11	120	61	04	13
12613	37	07086505000820	06	504	22	16	137	69	05	12
12614	33	07092003150570	08	541	28	16	146	67	06	09
12615	25	08089503650655	10	522	30	14	150	59	05	16
12621	34	07149504300944	10	487	27	14	155	65	04	13
12622	28	07103003720662	08	463	17	13	151	61	04	12
12623	31	07070202780661	09	514	25	13	157	62	04	15
12624	28	07112903250780	10	534	21	12	146	65	04	15
12625	30	07119002700508	10	543	34	17	177	61	05	16
12631	20	08078202730707	10	403	24	15	152	56	05	12
12632	18	07057701490433	05	433	18	09	124	60	04	13
12633	17	07079801820440	10	370	22	14	145	53	04	10
12634	18	06056501900400	09	430	32	16	142	59	04	14
12635	20	07116302990699	07	448	17	13	150	58	04	13
12641	24	08105003490734	09	483	32	17	150	54	04	13
12642	23	09109002320518	10	423	21	14	145	52	04	12
12643	37	07095204210869	07	508	26	15	160	60	05	15
12644	31	07072903110639	10	470	20	16	155	60	04	15
12645	40	08065204000866	10	543	27	18	160	60	04	16
12651	26	08082203410772	09	360	23	15	140	58	04	13
12652	16	07082502350788	10	517	31	14	153	56	04	11
12653	30	07103503500874	09	523	21	13	137	56	04	10
12654	34	07079002700674	09	520	25	15	160	59	04	13
12655	29	08090101820492	10	464	36	17	165	63	05	13
13111	34	06131804900948	06	455	22	17	159	58	05	15
13112	23	06046701330238	10	494	29	16	173	58	05	15
13113	39	07081205001006	10	506	28	14	143	65	06	12
13114	20	07056002130426	09	471	24	10	129	78	05	11
13115	36	03068905641257	09	586	25	15	166	59	08	09
13121	23	07054502770497	09	492	21	14	159	74	06	15
13122	22	07052701980490	09	469	21	17	167	55	05	09
13123	23	10116707801584	10	517	20	21	184	61	06	15
13124	20	06057001740404	05	494	21	14	152	80	06	10
13125	33	09094507471771	03	488	22	14	140	60	04	13
13131	35	08101404711098	10	449	31	17	150	54	04	14
13132	18	06063801850474	08	398	20	13	134	49	04	11
13133	17	05033500900149	09	565	28	15	126	60	04	09
13134	33	07069903300739	08	468	26	16	159	61	06	14
13135	20	06045201550334	09	558	22	13	133	50	04	12
13141	18	06049301320333	08	405	29	15	147	52	05	09
13142	21	08067302200562	08	387	22	15	142	56	06	08
13143	36	08060004200823	07	566	27	16	146	66	06	09
13144	32	07071002700612	10	508	24	14	149	55	05	09
13145	39	09136206831252	10	523	29	16	165	60	06	10
13151	25	07063302540649	09	364	28	14	156	58	04	10
13152	21	06044001070267	10	431	23	12	139	58	04	09
13153	23	06053002170579	10	473	31	14	168	62	04	12

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13155	26	07060002160423	10	531	27	15	155	58	05	09
13211	23	07064002710668	10	375	19	16	168	60	06	11
13212	23	07069302170542	10	380	23	16	164	62	04	12
13213	32	07072803000611	09	515	23	15	161	60	04	11
13214	32	08065303900726	08	520	22	13	142	61	04	13
13215	35	08088003700703	10	542	25	15	162	60	04	15
13221	28	07087003690797	09	492	24	16	148	59	06	09
13222	21	06067301940340	08	458	19	13	139	62	04	12
13223	20	07069002630546	10	515	23	17	174	59	05	12
13224	22	06068002450599	09	447	21	16	153	55	04	12
13225	20	06077702140640	07	423	20	11	131	78	04	10
13231	39	08122105040922	10	538	25	17	156	60	04	08
13232	27	09089704900781	10	522	26	16	163	58	04	10
13233	23	07101302950516	09	503	24	18	163	58	06	11
13234	25	07093903660488	10	510	27	16	155	53	05	11
13235	45	09106709121416	07	473	22	16	186	63	04	12
13241	30	06066602740533	06	427	24	18	170	57	06	13
13242	24	05034001140278	10	347	26	17	144	73	05	11
13243	39	07057404600679	05	367	31	17	168	59	04	12
13244	38	06099303200567	10	444	25	21	161	57	04	11
13245	35	09089004340803	09	467	31	18	171	59	05	14
13251	27	07100302900784	07	503	21	15	136	64	04	12
13252	21	05047201710408	07	512	30	12	134	64	04	10
13253	25	07076702300557	10	434	22	14	140	53	04	10
13254	34	06076302800716	10	514	26	17	165	54	04	10
13255	31	07084503770779	10	441	30	17	171	60	04	12
13311	29	07080003380689	10	467	21	17	155	54	06	08
13312	25	06059401790474	07	446	20	13	131	62	04	12
13313	29	06067002580560	09	484	20	17	168	65	04	12
13314	28	07087603900780	08	468	25	20	173	62	08	14
13315	33	07090303140679	10	432	22	14	149	63	05	14
13321	23	05042001170302	10	501	25	16	150	61	05	12
13322	22	05051001460344	08	382	17	16	169	67	05	13
13323	27	06071002920617	08	461	16	16	152	62	05	09
13324	36	05104002430596	09	472	26	16	158	69	04	13
13325	32	06082202250384	10	475	31	20	196	68	06	13
13331	28	07080303320684	10	452	20	11	126	66	04	12
13332	25	06057102030584	09	407	19	13	158	63	04	11
13333	25	07106603530306	10	481	26	18	173	72	06	15
13334	23	07078202170482	06	558	26	16	161	67	05	12
13335	24	05040001340194	10	530	21	15	164	66	04	10
13341	26	07069102640494	10	366	30	25	178	67	06	11
13342	23	06046001270331	02	445	20	16	157	66	05	11
13343	22	06074302300602	10	466	23	14	146	63	04	10
13344	30	07070503680627	10	490	31	15	163	71	06	12
13345	16	05055201010229	10	415	27	14	140	61	04	08
13351	28	08095803160764	10	403	23	16	164	63	04	14
13352	22	06044801600312	06	406	23	13	150	70	04	13
13353	22	07072801930444	10	426	26	13	152	65	04	15

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1	2	3 4	5	6	7	8	9	10	11	12
13354	27	08091603660687	09	505	26	14	159	68	04	16
13355	29	08128805200894	10	460	22	14	155	63	04	09
13411	22	06061401830495	09	444	24	18	160	63	04	08
13412	22	06055301720358	08	516	23	13	139	70	04	15
13413	23	06071702050334	09	414	23	12	149	67	04	14
13414	18	06061501320341	08	450	16	12	126	64	04	08
13415	25	07070403020693	08	434	21	14	156	60	05	11
13421	26	05054401850435	10	369	21	21	170	59	05	12
13422	24	05046601800430	10	390	30	15	146	64	04	14
13423	23	05046501640311	10	441	27	18	165	57	07	09
13424	27	04034301280222	10	301	15	13	146	67	05	11
13425	25	06047201900446	09	439	21	20	177	56	05	08
13431	24	07083203350764	08	400	21	15	162	65	05	14
13432	25	07082202250490	09	379	21	17	164	62	06	13
13433	23	08061202700500	10	456	21	17	161	64	04	12
13434	21	07081902220444	10	417	29	19	178	65	06	11
13435	30	08092803970717	09	428	27	21	173	59	06	15
13441	27	08083703600837	10	426	24	19	166	55	06	10
13442	29	07069002550493	09	527	24	18	154	60	04	09
13443	25	08076503460619	10	528	26	16	158	64	04	09
13444	23	07024802000174	02	335	22	14	185	51	04	14
13445	26	07058801170314	10	368	31	14	144	70	04	10
13451	28	07062503100551	10	498	32	19	185	62	07	14
13452	27	06063501800370	07	450	29	15	155	60	07	16
13453	37	06033402860590	02	460	32	15	131	54	06	09
13454	34	07059503900636	10	479	25	15	165	60	05	15
13455	33	06060902090361	10	390	32	18	174	63	04	16
13511	24	06060602010369	04	435	30	14	160	60	05	10
13512	25	06067402100412	10	359	21	12	132	66	06	10
13513	16	03070201750379	09	382	23	17	163	57	06	14
13514	29	08069802920376	10	495	23	19	169	53	06	15
13515	21	08069902350492	10	496	22	12	145	61	05	14
13521	29	07084003500647	09	311	31	18	165	61	05	13
13522	28	06076401730270	10	494	28	18	166	62	04	11
13523	30	08078303900535	10	439	23	16	166	62	05	12
13524	22	07102802120525	09	489	23	13	128	61	04	09
13525	27	07095303000641	05	475	20	14	141	63	04	15
13531	32	08097803970749	01	389	29	15	138	65	04	16
13532	27	07056202150392	09	312	29	16	151	69	05	14
13533	26	09106005250767	07	486	40	19	174	63	06	13
13534	30	08076503020751	08	512	30	15	156	65	04	12
13535	31	09160305510937	10	621	41	17	180	62	06	14
13541	25	08099602430696	09	473	22	14	148	58	04	15
13542	25	09111503620657	05	444	36	17	164	56	05	12
13543	28	09111305401086	10	608	22	19	161	56	05	11
13544	26	06054001900384	07	398	29	14	159	70	05	12
13545	22	07090202680566	06	323	20	12	132	62	04	14
13551	24	05032701100220	06	447	35	15	149	53	04	10
13552	27	07082002900547	04	447	25	12	136	61	04	12
13553	24	09085502960644	10	559	22	14	139	43	04	09

Appendix Table 2 continued

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13554	27	08070402940586	07	569	27	15	139	66	04	15
13555	38	10122805651259	09	535	35	22	202	68	06	16
13611	38	09094905260760	10	464	25	16	161	63	04	12
13612	21	07065602430459	07	459	30	15	159	61	05	10
13613	28	08078303520665	10	479	25	17	159	62	06	11
13614	28	08096803660661	09	536	19	16	175	64	07	12
13615	39	09125708671170	09	487	26	19	165	57	04	10
13621	23	07079002920579	10	411	20	12	137	67	04	12
13622	21	07106703120632	10	340	18	13	140	62	04	12
13623	30	08077404200731	10	460	26	17	174	66	05	15
13624	28	08070203290715	07	426	24	17	171	67	04	13
13625	39	08120304750756	10	395	27	19	174	62	05	11
13631	30	07073603470573	10	436	21	17	159	70	05	13
13632	23	07056002130421	09	351	22	16	135	65	04	13
13633	23	07087702120468	09	439	30	16	148	59	05	13
13634	33	06057502220381	07	435	31	15	159	55	04	09
13635	40	09115206771103	10	517	34	19	178	60	05	14
13641	21	07070102530538	09	466	22	12	149	67	05	14
13642	21	05037101040244	07	256	19	12	152	63	04	15
13643	28	07103003600577	10	520	25	14	145	59	05	13
13644	29	07065202860496	10	417	17	13	140	64	05	11
13645	34	07083203500500	10	404	24	16	172	61	04	13
13651	29	08080002920602	07	396	22	14	140	66	04	16
13652	16	07063402050382	09	378	18	14	146	66	04	15
13653	25	06074702100514	07	434	31	13	142	68	05	12
13654	26	07100602500614	10	465	32	16	161	65	04	10
13655	31	10132405201044	10	491	27	15	153	60	04	13
13711	31	07077803040755	09	374	25	16	151	62	05	13
13712	19	07057201600443	10	426	22	14	138	58	05	13
13713	26	09095004100979	10	483	22	14	160	60	04	12
13714	26	09106004831004	10	527	24	18	160	56	05	13
13715	27	08125603940680	06	443	18	17	145	54	05	14
13721	30	07089802770606	07	373	30	18	163	57	05	11
13722	26	05041301200264	06	404	21	12	144	62	04	11
13723	31	08086403550896	10	483	21	14	145	60	05	12
13724	33	08098305171032	10	557	23	16	152	52	06	13
13725	29	05058801750318	09	451	19	15	142	54	06	08
13731	31	08077103680697	07	425	34	15	140	64	04	15
13732	25	08064001880426	10	318	32	14	178	69	05	15
13733	23	08078902000567	10	488	29	16	155	66	06	13
13734	33	08093803800840	10	483	23	17	168	57	04	11
13735	24	07101302960707	07	553	24	15	146	56	06	11
13741	32	08087604450687	10	345	33	18	162	57	05	12
13742	22	05043201560352	10	314	35	15	142	62	04	08
13743	26	09093103850566	10	515	27	14	156	62	05	12
13744	27	09129103380640	10	488	21	16	160	57	05	13
13745	32	10187506340766	10	515	23	15	162	55	07	15
13751	31	08125803360658	10	385	24	14	141	58	05	10
13752	23	07063501580353	10	417	26	16	147	63	04	13
13753	30	08089303750899	07	540	25	17	147	75	04	13

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13755	24	0911550407084 3	09	508	22	15	155	60	05	12
13811	29	1007800250068 5	10	363	20	14	153	62	04	12
13812	28	0811310294034 2	10	343	25	12	158	60	04	15
13813	40	0708740385071 3	10	520	33	16	162	46	04	13
13814	24	0606200153049 8	07	344	23	17	160	55	04	13
13815	27	0707720205060 3	09	413	21	16	164	55	06	15
13821	34	0912680562092 9	10	464	23	15	155	60	05	09
13822	29	0704900185035 5	10	400	30	15	166	66	04	12
13823	30	0706250250057 4	10	376	21	14	149	57	04	11
13824	22	0604990110032 7	09	420	25	14	154	64	05	08
13825	32	0912480356089 7	04	521	25	15	135	64	04	12
13831	29	0709450241049 8	09	453	25	14	160	56	04	09
13832	29	0610600310049 3	10	467	21	12	142	52	04	09
13833	24	0708520275055 1	10	445	25	13	148	63	04	15
13834	24	0810090281050 9	10	500	22	17	147	58	04	12
13835	33	1010010403096 3	10	437	20	14	149	60	04	11
13842	18	0607430130032 9	10	447	21	15	157	62	04	11
13843	20	0402000057013 2	07	358	21	14	154	68	04	13
13844	15	0503130084021 5	10	383	22	16	161	65	04	12
13845	37	0814620457100 0	08	433	24	19	181	68	06	15
13851	24	0606730180051 0	10	395	23	14	160	66	05	11
13852	20	0706270161036 7	08	434	17	12	150	61	04	16
13853	27	0708460160042 6	10	420	20	14	154	70	05	11
13854	22	0707560239051 3	10	446	20	20	164	63	06	11
13855	33	0915300484098 2	10	505	25	19	175	65	05	12
13911	28	0708570400089 6	09	528	25	17	152	50	06	09
13912	22	0708030224055 0	10	478	23	14	145	61	04	11
13913	24	0708270414082 0	10	534	24	13	153	76	04	14
13914	26	0710740500114 8	10	465	27	18	165	58	06	13
13915	29	0912100583102 0	07	619	30	14	150	60	04	11
13921	25	0704370270061 7	10	475	36	16	160	62	08	10
13922	20	0905250132040 5	07	304	19	15	160	61	05	10
13923	21	0605000192040 5	10	409	22	15	150	61	05	11
13924	20	0608100210056 3	10	522	24	16	155	59	05	13
13925	23	0705450302063 1	10	523	18	16	154	63	04	11
13931	27	0809220400082 6	10	406	37	19	164	59	07	12
13932	21	0607250146044 6	09	495	26	16	139	66	04	11
13933	25	0811280416082 8	10	492	23	16	148	59	04	10
13934	23	0506450150038 3	08	540	23	14	158	66	04	12
13935	38	0912750646102 8	10	449	20	14	169	64	05	11
13941	33	0312360490101 0	10	536	29	17	163	64	06	12
13942	25	0811760282064 1	09	421	23	15	144	65	04	11
13943	25	0711000297057 0	09	564	20	13	157	58	05	13
13944	36	0708080452079 5	07	551	18	18	178	49	04	13
13945	29	0607560275067 4	10	509	23	21	176	71	06	16
13951	30	0706680290039 8	10	526	29	14	143	75	04	12
13952	25	0509380214045 0	09	466	19	12	145	59	04	12
13953	26	0706700247044 7	10	573	31	20	191	66	06	14
13954	10	0606260157039 0	10	444	28	11	107	54	04	10

Appendix Table 2 continued

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13055	31	08154003400724	10	459	26	16	157	60	03	11
14011	34	09092904301100	10	540	25	18	162	62	04	13
14012	18	06049001400344	08	447	24	15	142	58	04	15
14013	25	07072902430742	06	494	19	16	152	63	05	12
14014	35	09088105201087	07	488	19	17	164	67	05	12
14015	38	08144805681477	10	549	25	16	154	63	05	16
14021	28	07088103650820	10	375	26	13	164	66	06	13
14022	22	06055601370461	10	413	23	13	152	65	04	14
14023	30	07080003600820	10	495	25	16	156	62	04	13
14024	33	07088003700943	10	522	24	13	138	60	06	13
14025	19	07066801980455	10	405	22	13	156	64	04	15
14031	39	08105104490955	08	562	25	20	169	60	06	08
14032	22	05049001700374	10	514	20	15	161	61	06	11
14033	33	06065002500699	09	514	32	14	161	71	05	09
14034	31	07108003950784	06	514	18	14	140	64	04	09
14035	40	08159506101129	10	556	32	17	173	60	06	10
14041	26	07104903700984	09	479	25	15	151	53	05	08
14042	18	06078001250425	09	399	18	13	163	63	06	11
14043	34	07090703530904	10	549	27	13	157	57	04	15
14044	28	07093703030804	10	441	24	16	166	53	07	14
14045	24	07130002900969	10	455	23	13	153	66	04	12
14051	20	07094002850605	06	443	25	15	150	66	05	12
14052	21	08130003150725	10	431	21	19	148	43	04	09
14053	16	06065001000295	05	452	22	14	130	62	04	13
14054	22	07091502400635	07	460	24	13	135	62	04	14
14055	31	07220503800935	09	578	26	15	142	57	04	08
15211	31	07056902930557	09	485	22	20	168	60	06	12
15212	22	06058002100377	10	356	21	12	170	54	04	16
15213	31	07084603720864	09	493	22	21	188	52	04	12
15214	21	06081602220497	06	500	22	14	135	66	05	14
15215	22	07091803220816	10	545	22	15	145	60	04	13
15221	30	07085902600660	10	404	28	20	170	60	05	11
15222	20	04043601010296	10	338	20	11	151	57	05	10
15223	36	07084102670655	10	543	24	14	164	62	05	12
15224	33	06077702390773	09	558	20	16	154	57	04	08
15225	35	08124903720792	10	522	23	18	162	57	05	12
15231	26	07113503410927	08	459	18	16	155	61	06	13
15232	23	06062902010436	08	471	24	20	169	56	05	14
15233	25	07097902510535	08	442	22	16	161	53	04	10
15234	36	07068903210576	10	486	27	20	184	59	06	15
15235	29	07080503950817	10	416	21	17	155	64	04	13
15241	25	08078203100506	07	477	27	14	141	56	05	10
15242	26	07041102200339	05	372	19	18	157	60	05	13
15243	23	07053002800526	10	460	21	14	152	56	04	14
15244	31	07080503400711	06	507	24	16	164	59	06	15
15245	32	10150005351206	10	552	28	18	167	63	06	09
15251	19	05040501200263	08	429	21	17	163	66	05	13
15252	20	05049801270485	10	497	20	15	163	56	05	16
15253	28	05057002200442	03	437	21	14	155	62	06	13
15254	31	08099703250736	09	441	25	17	158	58	05	12

Appendix Table 2 continued

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15255	19	05051201260373	10	468	18	15	159	58	05	11
15411	22	06053201870467	08	306	19	16	159	55	04	12
15412	28	05040801600405	10	358	18	12	120	63	04	09
15413	30	05050501770318	10	532	21	18	170	59	06	10
15414	32	06081502500518	10	425	22	14	140	74	04	11
15415	24	05071001570415	10	439	24	18	170	64	05	11
15421	26	07082503200629	09	430	22	16	160	65	06	11
15422	23	04024201010226	10	340	27	14	153	66	04	10
15423	27	06052002350489	10	480	24	19	165	66	06	15
15424	28	07072602770638	10	489	23	17	155	56	06	13
15425	40	09141006101122	07	471	18	13	150	64	04	14
15431	25	07048502200503	10	405	23	17	164	65	06	08
15432	20	05048001150318	10	339	19	11	144	63	04	13
15433	23	07056002600528	10	430	22	17	161	60	05	12
15434	30	07081003370640	04	414	24	15	147	63	07	15
15435	20	05043601520366	07	427	20	17	142	63	05	12
15441	21	07066002520494	08	445	20	16	148	60	04	08
15442	19	06071001700468	10	342	21	16	147	54	04	09
15443	23	07079502980620	09	444	19	16	149	54	06	15
15444	24	07088803100578	08	478	22	19	162	57	05	13
15445	28	08104003720826	10	417	21	16	154	59	04	09
15451	27	08068203100500	09	461	20	16	155	59	04	11
15452	20	06056001920451	10	449	23	15	135	61	04	11
15453	30	09100505300927	10	549	24	18	150	60	06	12
15454	24	06072502270500	08	471	22	17	152	53	04	11
15455	34	09109005660908	10	495	23	23	181	57	05	11
15511	30	08074103700594	10	466	20	18	164	58	05	09
15512	21	07070002450622	10	395	28	19	154	64	04	10
15513	22	06047001850539	09	502	29	16	153	54	06	08
15514	19	05063501210504	09	419	20	17	150	58	05	10
15515	23	06062001700415	10	457	26	14	130	66	04	13
15521	16	04026900670164	08	457	27	14	150	55	04	10
15522	25	05037601260348	07	461	21	15	145	62	05	12
15523	25	06082002100405	09	531	28	17	164	59	05	11
15524	16	06093702000506	10	488	18	15	152	63	06	10
15525	29	07133803410806	07	428	31	15	155	65	06	15
15531	29	08103003690845	10	488	20	17	141	55	06	08
15532	22	06039501200226	10	441	23	18	145	56	04	11
15533	27	07088003360816	09	443	18	16	152	64	04	09
15534	24	07095003020639	10	413	26	17	156	64	06	12
15535	27	09115204431082	09	458	17	14	142	71	04	11
15541	19	07073102210537	10	437	21	12	135	57	04	09
15542	20	06062001790385	10	441	16	14	139	56	04	09
15543	37	07144003700737	09	552	20	16	154	57	04	12
15544	35	07060002490709	10	485	19	15	155	61	05	11
15545	35	07113503720669	07	515	21	16	162	64	05	09
15551	31	06078202550583	10	442	26	19	159	62	06	10
15552	26	06088002050514	10	462	19	12	149	69	04	12
15553	27	09096004751021	10	593	22	15	159	51	05	08
15554	18	04028300720193	10	373	30	14	138	64	05	10

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1	2	3 4	5	6	7	8	9	10	11	12
15555	32	03119004000792	09	472	34	16	154	63	04	08
22911	32	09097005300975	09	433	29	14	137	54	05	12
22912	22	09044002990521	03	529	22	10	134	59	04	13
22913	14	06059901400460	05	416	19	10	118	54	04	14
22914	25	05050002590556	10	511	27	12	143	52	06	10
22915	22	07052502700628	06	571	22	12	138	49	04	13
22921	27	09087505100910	07	472	22	13	123	53	04	11
22922	17	08057003550680	02	448	23	13	130	56	05	12
22923	32	08070004250740	07	542	26	13	117	59	07	12
22924	23	07057002300635	09	414	31	14	151	56	06	09
22925	20	07053502750645	10	576	28	14	132	51	06	08
22931	20	08069902910544	10	565	25	15	153	48	05	12
22932	17	06072901700431	09	481	21	11	126	53	04	12
22933	19	07067002900508	10	643	26	14	159	56	06	12
22934	16	10129803780761	10	584	18	17	151	55	05	08
22935	33	09086106221237	10	557	26	16	158	56	06	14
22941	16	08055103750710	10	536	26	12	130	60	04	09
22942	19	07042501610399	08	486	20	10	128	57	04	14
22943	18	09076003750926	09	795	32	11	128	51	04	13
22944	12	08049004400790	10	656	26	15	135	57	04	13
22945	19	08064502990671	08	652	31	15	149	56	07	14
23011	25	08070803320829	10	459	23	13	147	56	04	14
23012	22	07077801620430	09	402	17	10	139	65	04	09
23013	30	08109403420936	08	512	25	15	151	58	04	10
23014	30	07133403141047	10	455	21	17	156	59	05	11
23015	31	09075003921273	09	557	31	13	136	58	05	11
23021	29	08064003410724	10	469	25	13	155	65	05	09
23022	25	07079102290505	10	425	21	10	128	56	04	13
23023	31	08072003620781	09	484	21	19	154	59	04	12
23024	33	08078903350765	10	519	25	12	135	61	04	15
23025	33	07079103310606	08	567	24	15	145	60	04	14
23031	19	08065502420641	10	505	24	17	158	56	04	10
23032	22	08071001900654	10	485	21	16	160	56	06	11
23033	26	08092105251352	10	627	25	13	147	55	05	14
23034	28	06070401610794	08	519	25	16	142	59	05	10
23035	32	09150306081564	10	489	25	17	152	54	04	14
23041	19	07104602860825	10	631	26	18	159	54	06	12
23042	17	06050501540317	09	315	19	13	137	54	04	10
23043	30	07096104110907	09	421	28	18	168	59	05	11
23044	25	08095003310867	08	456	23	16	147	55	04	11
23045	24	05072001610405	10	367	22	12	119	66	04	10
23051	27	07073902700822	10	399	21	14	146	75	04	11
23052	25	07057901890437	08	416	22	16	168	67	04	11
23053	26	09089003520737	10	496	23	17	182	59	04	11
23054	29	08083704201055	09	463	20	17	147	55	05	09
23055	25	07068302690689	10	512	19	15	149	64	04	12
24111	25	07107202500617	10	488	17	15	132	44	06	10
24112	22	06047701990395	10	495	25	14	145	55	06	10
24113	26	05032601480283	10	440	20	16	158	61	06	11
24114	14	02005000320121	10	404	27	10	148	56	04	10

Appendix Table 2 continued

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24115	34	0809140373085З	10	474	22	16	165	68	04	11
24121	21	07043501770360	10	560	34	16	159	54	06	09
24122	18	06039001200212	09	454	24	13	143	55	04	12
24123	18	07069002420640	10	610	25	14	154	49	05	09
24124	13	06024601040218	10	486	18	11	136	63	04	09
24125	19	06036001300357	10	515	30	13	149	55	04	12
24131	29	07060603350525	10	474	27	20	171	66	04	09
24132	20	06053001530347	09	498	25	19	173	61	04	12
24133	20	07053501630437	10	603	26	14	154	56	05	11
24134	35	07055003750595	09	530	24	17	142	61	06	10
24135	39	10098505801316	10	548	30	15	162	63	04	14
24141	25	07067002170567	09	479	23	14	153	53	05	11
24142	20	06067301300408	01	500	24	13	127	59	04	11
24143	23	06031402030695	10	511	25	12	125	60	04	11
24144	25	07103002750577	05	523	26	16	143	55	04	11
24145	12	05054400650228	06	403	21	16	134	50	04	09
24151	25	07058802920557	10	414	23	13	153	66	04	11
24152	25	06065001620467	08	460	24	13	142	51	04	13
24153	30	06081003020853	03	476	22	14	162	70	04	15
24154	31	06077303200636	09	513	25	13	138	66	05	12
24155	30	07077403660803	10	542	25	14	149	63	05	11
24211	31	08055003290721	09	490	25	15	142	58	04	10
24212	16	06061501800410	03	487	24	12	136	55	04	15
24213	19	06085404550830	06	472	28	12	126	56	07	10
24214	22	07079003360698	10	518	24	12	139	73	04	12
24215	23	09135408971745	10	558	30	12	142	62	05	09
24231	24	07054703640556	08	458	32	16	150	48	05	14
24232	24	07070202360596	10	473	23	12	142	62	04	11
24233	22	06051002060766	10	638	26	17	155	60	04	12
24234	23	07067602820588	10	606	24	14	153	55	05	09
24235	20	06051201580457	08	344	22	12	139	66	05	11
24251	25	07063004581074	10	493	27	12	148	62	04	11
24252	18	08043002000402	09	505	19	16	155	59	04	10
24253	28	07041202330464	10	447	22	12	150	56	04	11
24254	17	08085402730926	06	543	27	14	149	65	05	12
24255	38	10068203800999	09	625	27	14	152	60	05	13
24411	22	08075004001014	04	594	27	14	125	59	04	10
24412	10	07053501650764	06	378	26	13	129	64	04	14
24413	21	06036502800549	05	486	24	16	131	56	04	13
24414	19	06052002200544	08	492	20	16	160	47	05	14
24415	09	06057501950469	07	445	19	11	115	50	04	12
24421	15	07045001730535	07	421	21	14	162	65	04	12
24422	11	08040401610445	07	388	22	11	113	53	04	14
24423	13	06035501430408	05	503	23	13	134	55	05	12
24424	13	05044201530495	07	502	21	13	150	61	04	13
24425	09	08063802350648	06	594	23	08	120	52	04	10
24431	13	07057002150454	10	434	18	12	145	63	05	13
24432	14	08075202050614	10	501	19	11	140	56	04	12
24433	20	08058902610678	10	510	23	14	152	61	04	11
24434	15	10114903950885	10	596	21	12	137	56	05	08

Appendix Table 2 continued

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24435	14	07070002300998	10	590	20	15	135	62	06	16
24441	16	09064205700900	09	602	23	14	154	60	05	10
24442	20	08083603520820	10	529	22	11	128	52	04	16
24443	28	09130005621228	07	621	25	14	155	59	06	13
24444	13	05035901090369	10	415	25	10	113	57	04	12
24445	34	11132508211841	10	581	24	18	150	59	05	10
24451	17	07050002350563	02	450	28	13	135	49	04	10
24452	15	07035001900463	08	549	24	10	130	54	04	08
24453	16	08067003700748	10	530	23	13	155	55	05	12
24454	16	08034001300278	06	498	24	09	120	61	04	08
24455	15	06058901490529	09	553	26	11	140	67	04	13
24511	16	08057002500594	09	498	22	10	107	60	04	09
24512	14	07045002250561	06	567	25	14	133	56	04	14
24513	15	09072502760786	06	653	33	14	141	63	05	16
24514	24	12081507001289	09	693	22	10	132	51	04	09
24515	11	07074001600584	03	439	29	10	104	71	04	11
24521	13	08072002420753	06	564	24	11	135	56	04	10
24522	22	09058003600700	09	532	29	14	133	67	06	14
24523	20	08047703600703	10	540	27	11	135	64	05	13
24524	14	06049501510419	10	552	23	13	144	50	05	09
24525	21	09090003251065	10	536	26	14	142	59	05	12
24531	18	10071503700923	10	585	26	12	148	63	06	09
24532	15	10049503700748	08	465	22	15	125	59	04	15
24533	26	10067505050993	09	731	32	13	149	47	06	14
24534	25	07049503750593	05	652	30	13	147	60	07	12
24535	21	10076004350963	10	646	30	13	140	58	06	12
24541	16	07061502210669	10	525	27	14	142	56	04	10
24542	18	08063201900630	10	443	25	12	120	40	04	12
24543	19	08070702850824	09	556	26	10	125	69	04	11
24544	25	09092003500860	08	533	31	15	142	60	05	12
24545	14	08101202400740	10	598	25	12	151	57	04	11
24551	25	09072003691024	07	542	25	16	155	59	06	10
24552	11	05040500850389	08	472	24	16	140	60	06	12
24553	23	07095003450853	10	578	23	14	125	59	04	11
24554	23	07137002700832	10	634	26	15	150	53	06	12
24555	27	10106006591575	10	614	28	15	144	63	05	14
32711	20	08068503620772	08	671	25	14	145	57	04	13
32712	20	06074801940584	10	464	22	11	143	66	04	08
32713	31	09076007531395	10	506	24	14	157	64	04	13
32714	26	07060002800636	05	568	23	12	151	55	04	16
32715	40	12075609661892	10	585	24	17	179	69	04	15
32721	16	06043401350456	08	539	40	14	141	62	05	12
32722	24	06063102070636	07	507	19	13	117	35	04	09
32723	24	06132004000929	10	583	24	15	154	59	06	15
32724	27	08091403560738	09	583	20	11	136	58	04	13
32725	40	11190907971720	09	537	36	17	157	58	04	13
32731	26	08098004021045	07	465	27	16	143	59	05	13
32732	20	06050001400466	04	512	26	13	141	53	04	09
32733	27	08124406031204	05	559	30	11	132	61	04	14
32734	18	07082301940557	06	545	26	12	154	56	05	14

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32735	31	09169004841217	08	562	29	22	178	60	07	14
32741	26	08106003350738	10	502	21	14	142	53	06	10
32742	18	07080302480657	08	468	26	11	121	54	05	11
32743	22	10103203801107	10	576	23	16	152	66	07	11
32744	17	07062002250468	07	452	20	16	157	61	06	08
32745	36	08074703840715	09	532	24	19	163	55	06	08
32751	28	09067003940884	09	398	28	17	153	63	04	09
32752	16	06037201330392	06	424	26	15	137	68	05	12
32753	29	08071404350850	10	339	24	14	152	51	05	09
32754	23	08112002430584	10	390	36	17	150	61	06	14
32755	29	09111404220875	06	505	20	12	145	74	04	13
32811	13	09065003850622	04	562	28	12	137	55	04	08
32812	06	05012400300050	06	393	18	17	139	58	06	11
32813	08	05026700900230	08	481	23	13	130	56	05	08
32814	10	05024900960216	03	549	18	08	115	63	04	10
32815	11	09064203740896	06	589	16	14	149	57	05	10
32821	13	10067804050797	09	588	22	14	150	56	06	11
32822	10	08044802010324	03	515	18	14	145	63	06	08
32823	08	10061802100469	05	530	20	11	138	53	05	09
32824	09	06035901000240	09	559	17	11	115	58	04	09
32825	15	09075906201244	07	651	20	14	141	49	05	10
32831	08	03066801360436	08	508	20	12	138	57	06	12
32832	12	08037802250456	07	517	20	11	137	56	05	09
32833	10	08048402020371	04	584	24	16	138	48	05	09
32834	12	11072804381196	06	737	22	10	120	56	09	10
32835	15	11070303391158	10	678	21	16	167	60	07	13
32841	12	10052003410846	04	435	22	12	143	53	04	09
32842	08	11043501840286	10	605	35	16	152	52	06	09
32843	10	11027502730421	04	583	18	10	117	60	04	12
32844	10	11084004400762	07	680	21	11	135	56	06	16
32845	17	13064506051099	06	607	25	14	149	58	04	14
32851	14	06020004750469	04	354	23	13	125	57	04	15
32852	18	08067204300690	01	558	25	14	136	45	05	12
32853	15	08046003380729	10	506	23	12	123	56	04	08
32854	15	09063804210703	03	638	23	10	130	67	04	16
32855	22	09082307101130	03	632	27	13	135	61	05	12
34311	08	06041401480615	03	560	29	09	115	54	06	08
34312	18	06044602020689	02	492	27	10	122	81	04	12
34313	11	08044201700626	09	595	31	14	162	55	06	10
34314	13	07069702751103	10	556	25	13	163	54	04	14
34315	11	08070802030854	10	614	25	11	127	57	05	10
34321	16	09083004751030	06	650	40	16	146	57	05	11
34322	14	07049002640701	09	540	29	14	143	58	04	12
34323	21	10069004320823	08	537	27	10	151	63	04	14
34324	16	08067504780867	08	560	25	13	151	54	04	13
34325	18	08060004200884	10	644	24	13	145	51	04	12
34331	16	08073503600895	04	565	24	12	114	58	04	11
34332	14	05035500950406	04	355	22	11	099	63	04	09
34333	10	06038001150304	03	557	22	13	150	61	04	12
34334	10	06038001140408	07	534	22	13	143	51	04	08

Appendix Table 2 continued

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34335	13	070770026009995	09	540	25	13	130	55	04	11
34341	12	080710033330771	08	455	17	13	150	55	06	12
34342	10	100664025105530	02	567	24	16	140	62	05	10
34343	11	080535022005583	08	493	19	13	148	51	06	08
34344	14	070660026005779	10	462	20	12	141	49	05	09
34345	08	070412016805581	07	421	16	13	146	65	06	11
34351	09	070507016505509	04	418	25	09	121	52	04	12
34352	10	060500017006629	05	545	23	13	120	58	04	10
34353	16	090660045910005	01	600	25	14	122	57	04	12
34354	14	101090048009944	08	538	22	13	141	55	04	10
34355	10	070640018205599	06	642	32	16	150	64	06	13
34611	11	120671038407741	07	500	19	16	152	65	05	08
34612	11	110631035909959	05	634	28	16	162	53	05	14
34613	10	100647033807753	10	470	22	14	145	60	05	10
34614	13	110730036910038	03	569	26	14	149	66	04	08
34615	12	100589029308882	10	678	30	16	153	51	05	09
34621	13	100680044010012	10	543	30	14	140	59	04	11
34622	10	110686041907761	06	693	26	20	159	62	04	14
34623	15	100649036306670	10	766	31	12	134	54	04	09
34624	12	110684045408830	10	707	30	12	149	59	05	14
34625	11	070293014303394	06	395	28	16	181	57	07	15
34631	13	110750044108867	06	554	24	14	128	61	05	12
34632	12	090383021506605	09	615	31	14	155	67	08	15
34633	16	100725041206636	10	652	23	12	126	52	04	13
34635	11	070673019305513	10	627	24	15	151	55	04	10
34641	12	100902033610058	05	570	39	12	138	60	04	15
34642	11	150890041907788	03	575	22	12	122	62	04	12
34643	12	080619031108877	05	633	25	09	111	62	04	12
34645	12	030592015805503	10	546	25	09	105	62	05	11
34651	11	110630037006617	10	626	17	12	137	52	04	09
34652	10	110722030005541	07	585	23	10	126	64	05	12
34653	13	110559041207752	07	697	24	14	142	61	04	13
34654	10	100695023505570	06	515	21	14	137	66	04	10
34655	18	110899052008887	10	618	22	14	148	61	05	11
34711	09	090590026006618	04	459	19	08	110	59	04	08
34712	10	110595025005573	09	587	21	10	102	59	04	09
34713	08	070455014003363	09	569	22	13	129	62	06	11
34714	08	100585020505553	03	542	25	12	121	65	05	09
34715	09	080765024506603	06	521	16	11	112	56	06	10
34721	15	100633035507710	03	462	20	12	133	64	05	11
34722	09	090792022605594	09	533	17	12	142	51	04	11
34723	10	070426022106611	05	675	18	13	129	61	05	11
34724	17	130661050711113	05	687	18	15	142	64	04	12
34725	15	080930034008868	10	668	27	11	136	54	04	09
34731	12	100618031206666	04	572	21	12	120	56	04	10
34732	07	070251009500130	03	555	19	09	114	62	06	11
34733	08	070341013004428	05	445	22	08	105	47	04	11
34734	09	070431013502278	06	601	29	12	120	56	06	12
34735	06	060449009204411	01	364	15	09	112	67	04	10
34741	10	110741031909912	02	499	20	12	115	63	04	08

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1	2	3 4	5	6	7	8	9	10	11	12
34742	10	10059202390552	04	508	26	12	130	60	04	11
34743	12	09082503390732	05	554	18	13	123	52	04	11
34744	10	09082002880734	01	507	16	12	118	58	04	12
34745	11	09090903810720	02	577	28	11	122	56	05	11
34751	09	12048803000620	08	532	17	12	129	60	04	09
34752	08	09042501500310	07	564	21	12	130	58	04	10
34753	16	11092002950639	07	638	33	12	146	61	04	13
34754	05	06039800900265	03	411	17	10	121	65	04	13
34755	07	08028001020258	05	504	16	12	142	53	04	09
34821	09	10066002410765	04	633	22	18	162	53	04	11
34822	08	07049001920528	04	571	23	12	122	59	04	11
34823	09	08067702020719	05	707	15	14	130	55	05	11
34824	06	03003500210044	05	700	33	15	152	60	05	11
34825	08	09063902020574	07	565	18	11	127	58	05	10
34841	09	07052601810582	05	561	21	15	141	57	04	10
34842	09	09063101500492	09	594	20	17	149	54	06	10
34843	10	08059001470615	09	497	20	14	135	56	04	14
34844	08	07044101200368	04	551	20	12	141	59	04	09
34845	09	10077002200644	08	516	15	12	142	61	05	11
34851	11	10066803250548	09	437	16	14	121	75	04	10
34852	09	09033601910378	08	462	21	18	132	51	04	11
34853	11	08067201900629	08	652	26	14	137	57	04	10
34854	11	08040002240418	07	551	20	13	132	60	04	09
34855	11	10078302500724	09	467	21	14	121	56	04	12
34911	06	11063001850483	06	554	21	13	133	57	04	11
34912	09	12064503150583	08	434	16	13	146	49	04	11
34913	12	09035502500528	09	539	24	12	133	59	04	13
34914	12	09075002750708	06	523	16	10	130	60	04	12
34915	09	09058502100833	08	561	32	12	133	56	04	10
34921	09	08047801760507	08	549	17	12	136	62	04	11
34922	07	08050501530590	10	525	16	10	121	57	04	14
34923	08	06034000920356	09	495	18	11	123	59	04	12
34924	09	08054901820567	07	615	24	16	170	58	04	09
34925	07	06036000900247	05	444	23	13	150	67	04	09
34931	13	12060203320595	09	636	34	14	150	60	04	10
34932	11	10059502390750	10	544	31	18	170	55	05	12
34933	13	10072304000840	07	697	23	14	143	60	04	08
34934	13	11064503700898	09	606	19	15	155	60	04	13
34935	11	09085202680743	05	656	35	13	161	60	06	10
34941	10	10058902800544	09	574	19	10	136	64	04	12
34942	09	07042001200315	07	564	18	10	133	52	04	10
34943	10	10052102500916	00	586	20	13	130	59	04	11
34944	11	13060002550749	03	498	17	08	126	65	04	15
34945	08	09053501920685	09	542	18	13	125	55	04	12
34951	13	08060303220794	08	566	27	12	121	55	05	10
34952	05	07032101000299	07	531	17	10	142	56	06	11
34953	05	06040000760226	04	492	20	12	123	61	05	08
34954	07	07041501310389	04	525	21	14	140	53	05	11
34955	13	08053202330531	08	652	31	18	145	54	04	13
35011	18	10063303540943	06	603	22	13	135	60	04	13

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1	2	3 4	5	6	7	8	9	10	11	12
35012	07	07046301370403	08	559	19	17	155	56	04	11
35013	11	05055001400474	10	395	19	11	135	55	04	08
35014	20	07072503150888	10	541	19	14	152	53	07	10
35015	11	08069602500589	10	618	19	12	145	59	05	09
35021	12	07047202300895	08	558	24	11	129	54	04	12
35022	10	06040401980423	09	461	19	11	137	61	07	08
35023	09	07037101840569	03	625	27	15	144	56	04	11
35024	10	08059302560738	05	648	26	10	139	61	05	10
35025	22	10103406351566	08	567	19	12	140	58	05	09
35031	09	07055001200437	05	504	18	14	138	53	06	08
35032	10	08041501950554	08	570	24	14	121	54	08	10
35033	09	06032001260397	10	512	20	10	121	60	04	09
35034	08	10058502350622	05	600	21	11	139	53	04	11
35035	14	11068003941228	10	564	22	15	161	67	05	12
35041	11	07042901190595	10	501	26	12	140	46	04	12
35042	11	10053803140700	07	574	23	12	140	51	06	11
35043	13	08065802350676	06	635	22	13	132	53	04	10
35044	17	08060104450793	06	583	18	15	143	55	04	08
35045	17	12072305211463	08	689	18	15	155	52	05	13
35051	13	12107303700710	06	590	21	13	122	49	04	10
35052	08	07047401120307	10	571	16	12	144	60	04	11
35053	12	11076005051065	06	633	20	16	161	53	04	08
35054	05	03010000170073	02	706	28	14	135	61	06	11
35055	09	06091301200551	09	538	19	12	115	51	06	09
35311	08	08026701740357	01	384	15	10	115	56	04	09
35312	11	06018000980236	02	523	28	11	115	45	04	09
35313	14	08050003240723	02	466	16	12	120	56	04	11
35314	23	07146003490833	10	519	20	15	164	64	04	15
35315	09	08034301550530	02	450	16	13	115	57	05	10
35321	13	09046403470540	06	532	19	10	124	64	04	11
35322	08	07037801200254	05	382	16	13	126	63	04	14
35323	06	06025500660205	05	492	17	09	118	63	04	13
35324	10	10046102350490	02	465	18	12	131	73	04	12
35325	10	10036002420471	09	327	20	17	142	63	04	15
35331	16	09062003820439	04	406	17	13	120	67	05	13
35332	09	06019300900229	04	453	21	15	129	61	05	11
35333	10	07059802900400	03	671	36	13	147	59	06	13
35334	13	08055201030453	00	557	29	10	115	59	04	09
35335	09	05043303270844	00	568	30	18	123	53	04	12
35341	08	10037501670311	04	503	20	11	131	59	04	13
35342	06	07030400750258	05	458	18	14	153	60	05	10
35343	10	10050001820511	05	509	26	12	156	60	04	14
35344	12	09031402620456	05	497	23	14	150	64	04	14
35345	09	08060001570394	03	482	22	14	134	68	06	11
35351	11	11055503220687	03	506	18	12	110	46	04	14
35352	09	09046401570309	02	408	28	10	112	63	04	11
35353	13	07060602050330	00	492	28	11	115	56	04	10
35354	12	09044202630484	04	538	18	13	134	67	04	13
35355	10	08029901640360	06	371	16	16	162	71	07	13

KEY TO APPENDIX TABLE 3

Column no.	Item
1	Row plot identification. The first digit indicates group number; the second and third, stand number; the fourth, mother tree number; and the fifth, replicate number.
2,3,4	Data not pertinent to the study.
5	Number of seeds sown.
6	Number of seeds germinated as of 3/29.
7	Number of seeds germinated as of 4/10. $\frac{\text{Col. 7}}{\text{Col. 5}} \times 100$ = germinability in per cent. Also, $\frac{\text{Col. 6}}{\text{Col. 7}} \times 100$ = speed of germination in per cent.
8	Sum of the numbers of cotyledons on a sample of seedlings (see Col. 9).
9	Number of seedlings on which cotyledon counts were made. $\frac{\text{Col. 8}}{\text{Col. 9}}$ = number of cotyledons per seedling.
10, 11	Data not pertinent to the study.

Appendix Table 3.--Progeny data of Nursery Test 2

1	2	3	4	5	6	7	8	9	10	11
10111	399	56	10	44	38	41	74	10	39905600014035	9268
10112	338	57	10	44	39	42	70	10	33805700016864	9286
10113	412	61	10	42	36	38	73	10	41206100014806	9474
10121	346	44	10	44	13	18	67	10	34604400012717	7222
10122	323	35	10	44	14	24	64	10	32303500010836	5833
10123	271	43	08	42	09	12	63	10	33865375015667	7500
10131	306	42	10	44	20	31	71	10	30604200013725	6452
10132	301	39	10	44	08	29	66	10	30103900012957	2759
10133	281	39	10	44	16	31	67	10	28103900013879	5161
10141	403	49	10	44	17	24	70	10	40304900012159	7083
10142	356	44	10	44	11	24	67	10	35604400012360	4583
10143	429	51	10	44	13	20	65	10	42905100011888	6500
10151	375	48	10	44	26	33	74	10	37504800012800	7879
10152	405	55	10	44	19	32	71	10	40505500013580	5938
10153	445	50	10	43	22	34	67	10	44505000011236	6471
10211	353	45	10	44	18	23	76	10	35304500012748	7826
10212	321	47	10	44	17	25	75	10	32104700014642	6800
10213	383	58	10	44	11	15	76	10	38305800015144	7333
10221	420	47	10	44	25	32	66	10	42004700011190	7813
10222	405	49	10	44	26	31	68	10	40504900012099	8387
10223	365	45	10	44	19	29	66	10	36504500012329	6552
10231	388	41	10	44	24	31	69	10	38804100010567	7742
10232	413	45	10	44	28	35	72	10	41304500010896	8000
10233	416	52	10	43	19	32	70	10	41605200012500	5938
10241	333	35	10	44	09	23	66	10	33303500010511	3913
10242	330	35	10	44	14	27	64	10	33003500010606	5185
10243	377	44	10	44	18	31	64	10	37704400011671	5806
10251	359	39	10	44	13	21	69	10	35903900010864	6190
10252	482	52	10	44	30	34	72	10	48205200010788	8824
10253	443	47	10	44	17	30	70	10	44304700010609	5667
10311	411	41	10	44	25	36	73	10	411041000 9976	6944
10312	370	56	10	44	24	33	72	10	37005600015135	7273
10313	327	44	10	43	30	34	68	10	32704400013456	8824
10321	291	36	08	44	01	04	25	04	36384500012371	2500
10322	354	44	10	44	05	08	54	06	35404400012429	6250
10323	389	48	10	43	07	12	71	10	38904800012339	5833
10331	441	53	10	44	23	25	72	10	44105300012018	9200
10332	381	63	10	44	21	24	75	10	38106300016535	6750
10333	410	54	10	43	19	21	75	10	41005400013171	9048
10341	424	63	10	44	23	29	68	10	42406300014858	7931
10342	363	54	10	44	29	31	70	10	36305400014876	9355
10343	407	55	10	44	24	30	68	10	40705500013514	8000
10351	430	56	10	44	07	13	78	10	43005600013023	5385
10352	383	58	10	44	20	30	79	10	38305800015144	6667
10353	368	49	10	44	10	18	78	10	36804900013315	5556
10411	401	46	10	44	13	19	76	10	40104600011471	6842
10412	394	50	10	44	22	33	76	10	39405000012690	6667

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
10413	362	47	10	44	26	31	77	10	36204700012983	8387
10421	332	55	10	44	14	25	79	10	33205500016566	5600
10422	381	49	10	44	21	26	82	10	38104900012861	8077
10423	344	54	10	44	27	31	79	10	34405400015698	8710
10431	391	58	10	44	17	20	76	10	39105800014834	8500
10432	338	43	10	44	26	28	74	10	33804300012722	9286
10433	337	53	10	44	20	25.	77	10	33705300015727	8000
10441	327	57	10	44	20	37	64	10	32705700017431	5405
10442	272	44	10	44	33	33	66	10	27204400016176	10000
10443	308	62	10	44	23	27	67	10	30806200020130	8519
10451	060	09	02	44	01	01	14	02	30004500015000	10000
10452	122	17	04	44	03	06	34	05	30504250013934	5000
10453	107	14	04	43	02	04	20	03	26753500013084	5000
10511	333	46	10	44	17	28	79	10	33304600013814	6071
10512	383	52	10	44	08	27	76	10	38305200013577	2963
10513	355	45	09	43	04	11	74	10	39445000012676	3636
10521	364	58	10	44	32	32	80	10	36405800015934	10000
10522	383	56	10	44	24	26	71	10	38305600014621	9231
10523	400	64	10	44	18	23	74	10	40006400016000	6429
10531	347	43	10	44	15	26	68	10	34704300012392	5769
10532	362	44	10	44	07	27	64	10	36204400012155	2593
10533	364	50	10	44	05	17	64	10	36405000013736	2632
10541	359	44	10	44	14	22	72	10	35904400012256	6364
10542	331	50	10	44	20	30	68	10	33105000015106	6667
10543	304	45	09	43	07	08	59	09	33785000014803	8750
10551	338	40	10	44	22	23	71	10	33804000011834	9565
10552	388	45	10	44	21	23	77	10	38804500011598	9130
10553	387	64	10	44	12	20	76	10	38706400016537	6000
10611	429	46	10	44	13	38	73	10	42904600010723	3421
10612	369	50	10	44	11	31	73	10	36905000013550	3548
10613	391	64	10	43	08	26	68	10	39106400016368	3077
10622	364	43	10	44	10	12	70	10	36404300011813	8333
10623	303	61	09	44	01	08	59	08	34226777819605	1250
10621	385	51	10	44	08	11	65	09	38505100013247	7273
10631	161	36	05	44	03	07	39	05	32207200022360	4286
10632	441	60	10	44	15	16	79	10	44106000013605	9375
10633	341	49	09	43	06	11	72	09	37895444414370	5455
10641	348	65	10	44	11	25	70	10	34806500018678	4400
10642	327	42	10	44	18	28	68	10	32704200012844	6429
10643	403	63	10	44	06	22	70	10	40306300015633	2727
10651	380	63	10	44	25	28	77	10	38006300016579	8929
10652	366	61	10	44	23	24	74	10	36606100016667	9583
10653	352	52	10	42	07	17	69	10	35205200014773	4118
10711	363	59	10	44	21	24	71	10	36305900016253	8750
10712	396	54	10	44	16	23	72	10	39605400013636	6957
10713	396	57	10	44	05	11	72	10	39605700014394	4545
10721	400	49	10	44	13	23	72	10	40004900012250	5652
10722	381	44	10	44	08	16	75	10	38104400011549	5000
10723	311	40	10	44	05	12	77	10	31104000012862	4167
10731	396	53	10	44	30	28	78	10	39605300013384	10714

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
10732	406	54	10	44	28	34	79	10	40605400013300	8235
10733	417	52	10	44	23	31	74	10	41705200012470	7419
10741	361	64	10	44	35	36	69	10	36106400017729	9722
10742	331	52	10	44	31	38	69	10	33105200015710	8158
10743	343	54	10	44	22	30	70	10	34305400015743	7333
10751	502	62	10	44	32	34	70	10	50206200012351	9412
10752	386	57	10	44	25	31	66	10	38605700014767	8065
10753	411	56	10	44	27	34	65	10	41105600013625	7941
10811	449	59	10	44	24	27	83	10	44905900013140	8889
10812	393	50	10	44	23	25	79	10	39305000012723	9200
10813	451	61	10	44	20	23	78	10	45106100013525	8696
10821	412	45	10	44	05	07	58	07	41204500010922	7143
10822	452	51	10	44	10	13	83	10	45205100011283	7692
10823	125	17	03	44	03	03	16	02	41675666713600	10000
10831	431	50	10	41	28	29	89	10	43105000011601	9655
10832	413	46	10	40	36	36	84	10	41304600011138	10000
10833	415	57	10	38	28	28	85	10	41505700013735	10000
10841	377	55	10	44	23	35	80	10	37705500014589	6571
10842	428	50	10	44	38	38	82	10	42805000011682	10000
10843	419	59	10	44	33	35	79	10	41905900014081	9429
10851	403	49	10	44	18	24	80	10	40304900012159	7500
10852	421	46	10	44	25	28	76	10	42104600010926	8929
10853	446	52	10	44	13	16	77	10	44605200011659	8125
10911	428	50	10	44	41	41	69	10	42805000011682	10000
10912	404	44	10	44	37	40	75	10	40404400010891	9250
10913	465	62	10	44	30	33	74	10	46506200013333	9091
10921	311	43	10	44	27	35	70	10	31104300013826	7714
10922	417	47	10	44	26	40	73	10	41704700011271	6500
10923	405	52	10	43	19	27	71	10	40505200012840	7037
10931	437	53	10	44	38	43	74	10	43705300012128	8837
10932	465	55	10	44	30	33	72	10	46505500011828	9091
10933	415	55	10	43	22	27	73	10	41505500013253	8148
10941	352	41	10	44	09	25	69	10	35204100011648	3600
10942	329	40	10	44	12	23	67	10	32904000012158	5217
10943	363	44	10	43	01	13	62	09	36304400012121	769
10952	392	44	10	44	33	33	65	10	39204400011224	10000
10953	386	51	10	43	21	27	68	10	38605100013212	7778
10951	386	39	10	44	30	31	69	10	38603900010104	9677
11011	348	45	10	44	10	27	78	10	34804500012931	3704
11012	383	50	10	44	13	25	74	10	38305000013055	5200
11013	397	60	10	44	28	26	81	10	39706000015113	10769
11021	431	57	10	44	20	24	73	10	43105700013225	8333
11022	397	54	10	44	23	25	74	10	39705400013602	9200
11023	465	64	10	43	23	26	74	10	46506400013763	8846
11031	362	47	10	44	22	36	72	10	36204700012983	6111
11032	327	41	10	44	16	36	69	10	32704100012538	4444
11033	334	56	10	44	29	33	67	10	33405600016766	8788
11041	381	51	10	44	30	36	70	10	38105100013386	8333
11042	339	45	10	44	42	42	69	10	33904500013274	10000
11043	343	45	10	43	33	38	67	10	34304500013120	8684

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
11051	375	49	10	44	03	26	74	10	375049000013067	1154
11052	375	47	10	44	10	26	73	10	375047000012533	3346
11053	385	52	10	44	03	09	68	10	385052000013506	3333
11111	468	52	10	44	12	16	77	10	468052000011111	7500
11112	441	49	10	44	13	17	83	10	441049000011111	7647
11113	328	47	08	44	08	10	78	10	410058750014329	8000
11121	356	39	10	44	20	30	71	10	356039000010955	6667
11122	385	44	10	44	12	30	72	10	385044000011429	4000
11123	354	45	10	43	09	20	68	10	354045000012712	4500
11131	452	59	10	44	36	37	76	10	452059000013053	9730
11132	433	58	10	44	19	37	78	10	433058000013395	5135
11133	393	50	10	44	26	30	81	10	393050000012723	8667
11141	449	50	10	44	18	29	86	10	449050000011136	6207
11142	382	44	10	44	26	31	89	10	382044000011518	8387
11143	379	56	10	44	17	28	82	10	379056000014776	6071
11151	411	48	10	44	13	28	75	10	411048000011679	4643
11152	425	50	10	44	16	29	76	10	425050000011765	5517
11153	413	56	10	44	07	21	79	10	413056000013559	3333
11211	354	41	10	44	15	29	71	10	354041000011582	5172
11212	332	42	10	44	06	17	63	10	332042000012651	3529
11213	364	52	10	43	08	15	40	06	364052000014286	5333
11221	334	47	10	44	09	12	71	09	334047000014072	7500
11222	299	42	10	44	02	15	82	10	299042000014047	1333
11223	336	58	08	44	06	10	69	09	420072500017262	6000
11231	336	39	10	44	03	17	76	10	336039000011607	1765
11232	313	32	10	44	01	13	78	10	313032000010224	769
11233	199	27	06	43	01	04	32	04	331745000013568	2500
11241	407	58	10	44	20	34	82	10	407058000014251	5882
11242	368	61	10	44	18	34	84	10	368061000016576	5294
11243	438	60	10	43	28	37	83	10	438060000013699	7568
11253	218	30	06	44	02	09	55	08	363350000013761	2222
11251	335	37	10	44	03	13	76	10	335037000011045	2308
11252	325	40	10	44	00	11	74	09	325040000012306	
11311	340	44	10	44	29	39	75	10	340044000012941	7436
11312	288	48	10	44	31	36	78	10	288048000016667	8611
11313	368	58	10	44	18	31	78	10	368058000015761	5806
11321	439	59	10	44	30	31	85	10	439059000013440	9677
11322	349	47	10	44	31	31	85	10	349047000013467	10000
11323	386	58	10	44	25	27	83	10	386058000015026	9259
11331	412	46	10	44	13	28	74	10	412046000011165	4643
11332	314	49	10	44	12	18	71	10	314049000015605	6667
11333	406	55	10	44	19	19	72	10	406055000013547	10000
11341	398	50	10	44	19	27	71	10	398050000012563	7037
11342	302	39	10	44	28	32	79	10	302039000012914	8750
11343	375	56	10	44	13	25	75	10	375056000014933	5200
11351	425	50	10	44	28	35	75	10	425050000011765	8000
11352	334	42	10	44	29	33	72	10	334042000012575	8788
11353	371	53	10	44	20	30	76	10	371053000014286	6667
11411	378	44	10	44	29	33	73	10	378044000011640	8788
11412	364	53	10	44	30	35	77	10	364053000014560	8571

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
11413	378	50	10	44	20	28	73	10	37805000013228	7143
11421	379	44	10	44	33	38	76	10	37904400011609	8684
11422	394	55	10	44	30	37	77	10	39405500013959	8108
11423	469	58	10	44	37	42	78	10	46905800012367	8810
11431	379	42	10	44	35	43	78	10	37904200011082	8140
11432	344	55	10	44	41	42	74	10	34405500015988	9762
11433	397	47	10	44	23	39	78	10	39704700011839	5897
11441	316	40	10	44	26	34	75	10	31604000012658	7647
11442	400	40	10	44	27	29	75	10	40004000010000	9310
11443	422	45	10	44	13	24	69	10	42204500010664	5417
11451	386	40	10	44	36	43	74	10	38604000010363	8372
11452	397	56	10	44	40	41	74	10	39705600014106	9756
11453	385	45	10	44	27	41	73	10	38504500011688	6585
11511	381	42	10	44	26	39	71	10	38104200011024	6667
11512	348	42	10	44	21	34	74	10	34804200012069	6176
11513	383	45	10	44	26	29	72	10	38304500011749	8966
11521	489	55	10	44	26	35	79	10	48905500011247	7429
11522	418	42	10	44	30	35	77	10	41804200010048	8571
11523	400	56	10	44	25	28	66	10	40005600014000	8929
11531	434	60	10	44	22	24	76	10	43406000013825	9167
11532	387	42	10	44	17	25	72	10	38704200010853	6800
11533	357	50	10	44	14	13	79	10	35705000014006	7778
11541	423	51	10	44	13	32	87	10	42305100012057	4063
11542	348	42	10	44	13	31	88	10	34804200012069	4194
11543	378	47	10	43	05	16	93	10	37804700012434	3125
11551	316	40	10	44	19	26	70	10	31604000012658	7308
11552	308	40	10	44	25	35	76	10	30804000012987	7143
11553	339	52	10	44	08	17	74	10	33905200015339	4706
11611	396	40	10	44	28	33	79	10	39604000010101	8485
11612	349	41	10	44	26	29	73	10	34904100011748	8966
11613	452	47	10	43	15	23	74	10	45204700010398	7826
11621	399	48	10	44	25	40	74	10	39904800012030	6250
11622	406	50	10	44	32	35	72	10	40605000012315	9143
11623	390	55	10	43	25	29	79	10	39005500014103	8621
11631	387	45	10	44	31	33	66	10	38704500011628	8158
11632	375	45	10	44	28	35	70	10	37504500012000	8000
11633	400	46	10	44	22	32	70	10	40004600011500	6875
11641	390	55	10	44	24	33	77	10	39005500014103	7273
11642	375	47	10	44	32	37	73	10	37504700012533	8649
11643	445	43	10	42	23	30	70	10	445043000 9663	7667
11651	402	55	10	44	41	41	76	10	40205500013682	10000
11652	446	52	10	44	36	40	78	10	44605200011659	9000
11653	496	64	10	44	26	37	75	10	49606400012903	7027
11711	395	54	10	44	14	15	68	10	39505400013671	9333
11712	385	48	10	44	09	14	80	10	38504800012468	6429
11713	062	19	02	42	02	03	08	01	31009500030645	6667
11721	335	47	10	44	03	13	73	10	33504700014030	2308
11722	290	45	10	44	07	13	68	10	29004500015517	5365
11723	192	42	10	43	06	12	68	10	19204200021875	5000

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
11733	300	55	10	44	18	28	75	10	30005500016333	6429
11731	419	55	10	44	11	21	73	10	41905500013126	5238
11732	287	48	10	44	15	28	74	10	28704800016725	5357
11751	340	54	10	44	35	36	82	10	34005400015882	9722
11752	305	45	10	44	21	31	68	10	30504500014754	6774
11753	325	47	10	44	28	32	71	10	32504700014462	8750
11811	391	46	10	44	09	30	75	10	39104600011765	3000
11812	365	46	10	44	06	21	75	10	36504600012603	2857
11813	395	52	10	44	05	16	76	10	39505200013165	3125
11821	321	39	10	44	07	22	70	10	32103900012150	3182
11822	365	45	10	44	14	30	73	10	36504500012329	4667
11823	349	49	10	44	07	22	68	10	34904900014040	3182
11831	343	49	10	44	19	26	77	10	34304900014286	7308
11832	326	50	10	44	21	26	83	10	32605000015337	8077
11833	364	59	10	44	20	23	81	10	36405900016209	8696
11841	352	43	10	44	34	41	77	10	35204300012216	8293
11842	343	49	10	44	34	40	76	10	34304900014286	8500
11843	408	55	10	44	26	37	71	10	40805500013480	7027
11851	342	40	10	44	28	34	76	10	34204000011696	8235
11852	263	44	10	44	30	35	78	10	26304400016730	8571
11853	385	56	10	44	17	35	74	10	38505600014545	4857
11911	419	38	10	44	28	35	74	10	419038000 9069	8000
11912	374	39	10	44	30	35	81	10	37403900010428	8571
11913	439	52	10	44	35	40	79	10	43905200011645	8750
11921	414	48	10	44	06	25	76	10	41404800011594	2400
11922	295	39	10	44	01	28	76	10	29503900013220	357
11923	398	39	10	44	10	22	76	10	398039000 9799	4545
11931	509	60	10	44	26	36	77	10	50906000011788	7222
11932	411	50	10	44	35	42	82	10	41105000012165	8333
11933	554	56	10	44	32	38	77	10	55405600010108	8421
11941	446	45	10	44	10	18	81	10	44604600010314	5556
11942	344	38	10	44	10	17	75	10	34403800011047	5882
11943	372	43	10	44	13	19	75	10	37204300011559	6842
11951	397	47	10	44	24	39	77	10	39704700011839	6154
11952	339	39	10	44	28	36	73	10	33903900011504	7778
11953	341	44	10	44	29	39	77	10	34104400012903	7436
12011	405	58	10	44	31	33	77	10	40505800014321	9394
12012	349	43	10	44	23	28	76	10	34904300012321	8214
12013	415	58	10	43	27	31	75	10	41505800013976	8710
12021	353	47	10	44	31	35	69	10	35304700013314	8857
12022	351	48	10	44	29	35	66	10	35104800013675	8286
12023	376	44	10	41	24	32	69	10	37604400011702	7500
12031	365	41	10	44	14	19	67	10	36504100011233	7368
12032	357	39	10	44	12	23	71	10	35703900010924	5217
12033	419	51	10	44	16	17	70	10	41905100012172	9412
12041	311	49	10	44	16	35	73	10	31104900015756	4571
12042	249	33	10	44	06	27	70	10	24903300013253	2222
12043	352	43	10	44	08	28	66	10	35204300012216	2857
12051	362	51	10	44	19	25	69	10	36205100014088	7600
12052	341	37	10	44	12	25	77	10	34103700010850	4800
12053	513	54	10	44	19	27	72	10	51305400010526	7037

Appendix Table 3 continued

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12111	375	52	10	44	26	42	77	10	37505200013867	6190
12112	352	53	10	44	33	41	76	10	35205300015057	8049
12113	408	53	10	44	23	35	73	10	40805300012990	6571
12121	366	44	10	44	08	17	69	10	36604400012022	4706
12122	362	48	10	44	17	29	69	10	36204800013260	6071
12123	260	35	06	44	06	06	47	06	43335833313462	10000
12131	411	56	10	44	26	30	84	10	41105600013625	8667
12132	345	53	10	44	29	28	80	10	34505300015362	10357
12133	452	53	10	44	26	32	80	10	45205300011726	8125
12151	437	59	10	38	18	23	80	10	43705900013501	7826
12152	323	50	10	37	24	27	78	10	32305000015480	8889
12153	373	59	10	32	11	16	86	10	37305900015818	6875
12211	369	46	10	44	28	36	77	10	36904600012466	7778
12212	405	52	10	44	18	31	82	10	40505200012540	5806
12213	401	49	10	44	16	20	83	10	40104900012219	6000
12221	334	47	10	44	25	34	75	10	33404700014072	7353
12222	349	50	10	44	19	25	73	10	34905000014327	7600
12223	364	51	10	43	18	30	76	10	36405100014011	6000
12231	374	57	10	44	22	24	85	10	37405700015241	9167
12232	380	55	10	44	22	22	88	10	38005500014474	10000
12233	398	59	10	44	21	22	86	10	39805900014824	9545
12241	343	53	10	44	23	27	81	10	34305300015452	8519
12242	342	46	10	44	20	24	87	10	34204600013450	8333
12243	400	48	10	43	13	12	74	10	40004800012000	10833
12311	363	46	10	29	16	19	83	10	36304600012672	8421
12312	380	44	10	29	09	14	80	10	38004400011579	6429
12313	222	28	10	29	03	04	30	04	22202800012613	7500
12321	284	47	10	24	12	14	74	10	28404700016549	8571
12322	346	46	10	23	08	14	75	10	34604600013295	5714
12323	395	48	10	23	12	14	73	10	39504800012152	8571
12331	344	49	10	39	16	22	74	10	34404900014244	7273
12332	336	41	10	39	14	20	78	10	33604100012202	7000
12333	348	55	10	38	10	15	83	10	34805500015805	5556
12341	334	54	10	41	26	32	80	10	33405400016168	8125
12342	394	56	10	41	25	30	77	10	39405600014213	8333
12343	358	60	10	40	27	33	81	10	35806000015760	8182
12351	382	56	10	28	17	21	76	10	38205600014660	8095
12352	409	57	10	27	14	13	79	10	40905700013936	7778
12353	448	58	10	27	11	14	71	09	44805800012946	7857
12411	412	44	10	44	03	30	70	10	41204400010680	1000
12412	409	56	10	44	15	34	70	10	40905600013692	4412
12413	383	51	10	44	03	22	70	10	38305100013316	1364
12421	366	42	10	44	19	40	73	10	36604200011475	4750
12422	356	54	10	44	34	38	72	10	35605400015169	8947
12423	327	52	10	44	26	40	76	10	32705200015902	6500
12432	423	52	10	33	16	21	77	10	42305200012293	7619
12433	429	56	10	33	10	12	78	10	42905600013054	8333
12431	499	57	10	34	05	27	71	10	49905700011423	1852
12441	397	50	10	44	09	13	72	10	39705000012594	6923
12442	363	34	10	44	19	30	69	10	363034000 9366	6333
12443	332	47	10	44	12	26	65	10	33204700014157	4615

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
12451	364	42	10	44	01	19	73	10	36404200011538	526
12452	306	36	10	44	09	28	72	10	30603600011765	3214
12453	312	41	10	44	04	18	65	10	31204100013141	2222
12511	335	46	10	44	08	33	77	10	33504600013731	2424
12512	290	32	10	44	14	23	79	10	29003200011034	6087
12513	288	39	10	44	16	34	76	10	28803900013542	4706
12521	336	41	10	44	19	35	70	10	33604100012202	5429
12522	323	44	10	44	17	37	72	10	32304400013622	4595
12523	278	39	10	44	25	20	67	10	27803900014029	12500
12531	401	46	10	44	26	34	75	10	40104600011471	7647
12532	378	49	10	44	33	40	82	10	37804900012963	8250
12533	363	56	10	44	35	40	75	10	36305600015427	8750
12551	382	45	10	44	20	27	74	10	38204500011780	7407
12552	331	38	10	44	09	22	81	10	33103800011430	4091
12553	302	41	10	44	17	22	75	10	30204100013576	7727
12611	463	58	10	44	39	41	75	10	46305800012527	9512
12612	397	49	10	44	35	40	75	10	39704900012343	8750
12613	526	64	10	44	37	37	74	10	52606400012167	10000
12621	395	47	10	44	12	21	90	10	39504700011899	5714
12622	370	44	10	44	09	13	99	10	37004400011892	5000
12623	469	52	10	44	12	19	93	10	46905200011087	6316
12631	409	50	10	44	15	31	84	10	40905000012225	4839
12632	363	39	10	44	01	25	79	10	36303900010744	400
12633	429	54	10	44	15	31	79	10	42905400012587	4839
12641	450	46	10	44	29	35	73	10	45004600010222	8286
12642	331	37	10	44	12	26	70	10	33103700011178	4615
12643	479	51	10	43	18	28	76	10	47905100010647	6429
12651	388	41	10	44	26	34	74	10	38804100010567	7647
12652	268	30	10	44	12	24	76	10	26803000011194	5000
12653	425	39	10	42	12	26	74	10	425039000 9176	4615
13111	378	46	10	44	02	13	75	10	37804600012169	1538
13112	403	57	10	44	29	42	83	10	40305700014144	6905
13113	400	52	10	44	24	29	81	10	40005200013000	6276
13121	378	58	10	44	33	37	79	10	37805800015344	8919
13122	340	59	10	44	24	38	78	10	34005900017353	6316
13123	463	63	10	44	32	36	79	10	46306300013607	8889
13131	372	54	10	44	09	19	69	10	37205400014516	4737
13132	301	39	10	44	06	23	73	10	30103900012957	2609
13133	384	52	10	40	07	18	69	10	38405200013542	3889
13141	400	49	10	44	27	34	72	10	40004900012250	7941
13142	387	44	10	44	29	37	71	10	38704400011370	7838
13143	421	51	10	44	33	37	71	10	42105100012114	8919
13151	353	49	10	44	01	16	61	10	35304900013881	625
13152	362	33	10	44	01	11	64	10	362033000 9116	909
13153	317	34	08	44	00	10	51	08	39034250010726	
13211	367	43	10	44	26	34	81	10	36704300011717	7647
13212	381	47	10	44	16	27	78	10	38104700012336	5926
13213	403	45	10	44	09	12	74	10	40304500011166	7500
13221	355	43	10	44	18	26	74	10	35504300012113	6923
13222	314	42	10	44	08	14	63	09	31404200013376	5714
13223	370	53	10	40	08	16	74	10	37005300014324	4444

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
13231	391	50	10	44	25	32	71	10	39105000012788	7813
13232	403	47	10	44	28	32	73	10	40304700011663	8750
13233	453	59	10	44	25	28	68	10	45305900013024	8929
13241	370	39	10	44	09	20	71	10	37003900010541	4500
13242	432	42	10	44	07	14	67	10	432042000 9722	5000
13243	450	55	10	44	09	13	74	10	45005500012222	6923
13251	337	40	10	44	19	32	70	10	33704000011869	5938
13252	331	41	10	44	20	30	73	10	33104100012387	6667
13253	387	59	10	44	26	31	68	10	38705900015245	8387
13311	268	33	07	44	00	07	49	07	38294714312313	
13312	152	27	04	44	00	06	29	04	38006750017763	
13313	201	34	05	44	00	04	26	04	40206800016915	
13321	368	50	10	44	22	28	60	10	36805000013587	7657
13322	311	48	10	44	24	35	63	10	31104800015434	6857
13323	443	59	10	43	23	31	62	10	44305900013318	7419
13341	410	63	10	44	03	11	74	10	41006300015366	2727
13342	198	43	06	44	01	07	50	07	33007166721717	1429
13343	369	59	10	44	04	08	44	08	36905900015989	5000
13351	335	50	10	44	10	21	65	10	33505000014925	4762
13352	355	44	10	44	07	18	70	10	35504400012394	3889
13353	329	46	10	42	09	15	64	10	32904600013982	6000
13411	351	44	10	44	31	38	59	10	35104400012536	8158
13412	319	45	10	44	31	35	60	10	31904500014107	8857
13413	305	55	10	44	22	33	61	10	30505500016033	6667
13421	403	52	10	44	20	24	73	10	40305200012903	8333
13422	413	55	10	44	13	18	72	10	41305500013317	7222
13423	383	45	10	44	05	14	71	10	38304500011749	3571
13431	352	46	10	44	11	21	72	10	35204600013068	5238
13432	325	45	10	44	08	13	66	10	32504500013846	6154
13433	212	30	07	44	04	09	55	08	30294285714151	4444
13441	360	48	10	44	23	25	64	10	36004800013333	9200
13442	410	61	10	44	15	16	70	10	41006100014878	9375
13443	347	60	10	44	20	26	72	10	34706000017291	7692
13451	390	41	10	44	09	27	79	10	39004100010513	3333
13452	385	45	10	44	04	21	73	10	38504500011688	1905
13453	381	47	10	44	07	19	74	10	38104700012336	3684
13511	414	56	10	44	13	10	76	10	41405600013527	13000
13512	372	48	10	44	15	17	80	10	37204800012903	8824
13513	424	61	10	43	15	15	76	10	42406100014387	10000
13521	436	56	10	44	21	23	77	10	43605600012844	9130
13522	347	48	10	44	17	17	81	10	34704800013833	10000
13523	426	50	10	44	16	19	78	10	42605000011737	8421
13531	448	45	10	44	23	27	85	10	44804500010045	8519
13532	369	46	10	44	17	25	75	10	36904600012466	6800
13533	450	57	10	44	21	25	82	10	45005700012667	8400
13541	411	51	10	44	31	35	84	10	41105100012409	8857
13542	320	50	10	44	19	29	79	10	32005000015625	6552
13543	381	50	10	44	18	29	81	10	38105000013123	6207
13551	429	61	10	44	27	27	95	10	42906100014219	10000
13552	373	51	10	44	26	32	90	10	37305100013673	8125
13553	419	58	10	44	24	24	86	10	41905800013842	10000

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
13611	394	54	10	44	19	27	72	10	39405400013706	7037
13612	394	49	10	44	34	37	73	10	39404900012437	9189
13613	435	58	10	42	28	29	74	10	43505800013333	9655
13621	382	56	10	31	20	20	78	10	38205600014660	10000
13622	362	40	10	31	25	25	75	10	36204000011050	10000
13623	452	60	10	30	13	15	76	10	45206000013274	8667
13631	433	54	10	44	17	33	79	10	43305400012471	5152
13632	368	40	10	44	27	33	75	10	36804000010870	8182
13633	456	51	10	44	15	25	78	10	45605100011134	6000
13641	290	39	10	44	01	07	32	05	29003900013448	1429
13642	311	30	10	44	04	23	68	10	311030000 9646	1739
13643	411	51	10	44	01	15	76	10	41105100012409	667
13651	392	59	10	44	33	39	60	09	39205900015051	8462
13652	335	41	10	44	34	35	67	10	33504100012239	9714
13653	375	52	10	43	33	39	74	10	37505200013867	8462
13712	309	41	10	44	24	33	73	10	30904100013269	7273
13713	390	50	10	43	21	26	71	10	39005000012821	8077
13711	343	38	10	44	33	37	72	10	34303800011079	8919
13721	361	36	10	44	20	37	66	10	361036000 9972	5405
13722	382	42	10	44	21	35	65	10	38204200010995	6000
13723	441	52	10	43	21	29	65	10	44105200011791	7241
13731	370	43	10	44	25	29	78	10	37004300011622	6621
13732	377	46	10	44	13	22	88	10	37704600012202	5909
13733	388	42	10	42	06	10	76	10	38804200010825	6000
13741	335	42	10	44	37	38	76	10	33504200012537	9737
13742	350	56	10	44	26	30	81	10	35005600016000	8667
13743	454	68	10	44	34	35	71	10	45406800014978	9714
13751	426	42	10	44	33	36	72	10	426042000 7859	9167
13752	423	52	10	44	30	37	67	10	42305200012293	8108
13753	501	67	10	43	25	29	69	10	50106700013373	8621
13811	414	62	10	44	28	35	80	10	41406200014976	8000
13812	253	35	10	44	08	23	78	10	25303500013834	3478
13813	402	56	10	44	05	13	77	10	40205600013930	3846
13821	437	57	10	44	11	17	80	10	43705700013043	6471
13822	357	42	10	44	07	14	77	10	35704200011765	5000
13823	174	29	04	44	01	03	23	03	43507250016667	3333
13831	396	57	10	44	11	26	75	10	39605700014394	4231
13832	350	49	10	44	16	22	76	10	35004900014000	7273
13833	444	80	10	44	13	22	77	10	44408000018018	5909
13841	384	46	10	44	22	30	72	10	38404600011979	7333
13842	293	39	10	44	18	23	74	10	29303900013311	7826
13843	387	57	10	44	13	22	66	10	38705700014729	5909
13851	336	47	10	44	18	34	63	10	33604700013988	5294
13852	334	39	10	44	20	41	80	10	33403900011677	4878
13853	368	48	10	43	12	34	65	10	36804800013043	3529
13911	371	44	10	44	15	34	79	10	37104400011860	4412
13912	288	47	10	44	30	33	80	10	28804700016319	9091
13913	390	48	10	44	20	27	79	10	39004800012308	7407
13921	383	46	10	44	14	23	78	10	38304600012010	6087
13922	271	43	10	44	11	29	80	10	27104300015867	3793

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
13923	340	55	10	43	14	13	76	10	34005500016176	10769
13931	379	48	10	44	23	32	78	10	37904800012665	7188
13932	311	50	10	44	26	32	79	10	31105000016077	6125
13933	358	49	10	44	28	31	80	10	35804900013687	9032
13941	442	51	10	44	20	37	72	10	44205100011538	5405
13942	329	50	10	44	24	32	75	10	32905000015198	7500
13943	460	55	10	44	14	35	67	10	46005500011057	4000
13951	419	53	10	44	10	26	70	10	41905300012649	3846
13952	356	50	10	44	18	28	75	10	35605000014045	6429
13953	449	50	10	44	07	20	71	10	44905000011136	3500
14011	442	58	10	44	19	27	78	10	44205800013122	7037
14012	421	55	10	44	23	28	76	10	42105500013064	8214
14013	362	56	10	44	27	29	76	10	36205600015470	9310
14021	397	46	10	44	36	41	77	10	39704600011587	8780
14022	389	56	10	44	32	38	74	10	38905600014396	8421
14023	368	53	10	44	32	34	74	10	36805300014402	9412
14031	376	52	10	44	16	18	77	10	37605200013830	8889
14032	391	53	10	44	14	19	73	10	39105300013555	7368
14033	390	54	10	43	12	21	77	10	39005400013846	5714
14041	408	56	10	44	19	38	74	10	40805600013725	5000
14042	381	50	10	44	23	30	73	10	38105000013123	7667
14043	366	65	10	42	18	28	73	10	36606500017760	6429
14051	388	52	10	44	10	26	72	10	38805200013402	3846
14052	364	47	10	44	15	30	77	10	36404700012912	5000
14053	355	53	10	44	26	30	72	10	35505300014930	8667
15211	303	49	10	44	22	28	69	10	30304900016172	7857
15212	320	48	10	44	32	34	66	10	32004800015000	9412
15213	346	52	10	43	32	33	69	10	34605200015029	9697
15221	381	44	10	44	22	31	70	10	38104400011549	7097
15222	323	39	10	44	30	34	82	10	32303900012074	8824
15223	389	55	10	43	24	31	78	10	38905500014139	7742
15231	317	44	10	44	23	29	81	10	31704400013880	7931
15232	330	48	10	44	26	28	73	10	33004800014545	9286
15233	404	52	10	43	20	26	74	10	40405200012671	7692
15241	399	48	10	44	25	31	79	10	39904800012030	8065
15242	349	51	10	44	24	28	80	10	34905100014613	8571
15243	405	49	10	44	26	31	75	10	40504900012079	8387
15251	318	44	10	44	19	30	67	10	31804400013836	6333
15252	373	42	10	44	08	24	74	10	37304200011260	3333
15253	328	40	10	43	11	20	74	10	32804000012195	5500
15411	346	53	10	44	03	24	68	10	34605300015318	1250
15412	337	45	10	44	05	27	66	10	33704500013353	1852
15413	372	51	10	41	01	17	71	10	37205100013710	588
15421	378	45	10	44	12	13	73	10	37804500011905	9231
15422	289	43	08	44	09	09	50	07	36135375014879	10000
15423	375	59	10	45	09	09	51	07	37505900015733	10000
15431	321	41	10	44	14	27	65	10	32104100012773	5185
15432	334	42	10	44	06	22	70	10	33404200012575	2727
15433	342	49	10	44	07	17	66	10	34204900014327	4118
15441	351	50	10	44	10	16	73	10	35105000014245	6250
15442	337	47	10	44	15	25	76	10	33704700013947	6000
15443	362	52	10	44	09	17	80	10	36205200014365	5294

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
15451	386	53	10	44	10	19	78	10	38605300013731	5263
15452	361	50	10	44	10	19	81	10	36105000013850	5263
15453	414	61	10	43	06	12	75	10	41406100014734	5000
15511	349	43	10	44	12	35	75	10	34904300012321	3429
15512	364	48	10	44	24	36	74	10	36404800013187	6667
15513	293	42	10	44	23	31	76	10	29304200014334	7419
15521	355	35	10	44	00	06	52	07	355035000 9859	
15522	370	45	10	44	03	17	74	10	37004500012162	1765
15523	269	38	10	43	07	12	65	09	26903800014126	5833
15531	442	48	10	44	26	33	69	10	44204800010660	7879
15532	324	44	10	44	25	31	72	10	32404400015580	8065
15533	321	48	10	44	23	28	74	10	32104800014953	8214
15541	429	52	10	44	27	42	78	10	42905200012121	6429
15542	394	52	10	44	34	38	79	10	39405200013198	8947
15543	340	52	10	44	35	39	76	10	34005200015294	8974
15551	386	39	10	44	04	17	72	10	38603900010104	2353
15552	359	39	10	44	07	21	84	10	35903900010864	3333
15553	280	36	10	43	09	15	75	10	28003600012857	6000
22921	077	22	04	21	04	04	18	03	19255500028571	10000
22922	171	31	06	21	02	03	29	05	28505166716129	2500
22923	055	12	02	20	02	02	10	02	27506000021818	10000
22941	218	62	10	22	15	16	82	10	21806200026440	9375
22942	222	62	10	22	09	11	72	07	22206200027928	8182
22943	231	70	10	21	09	12	77	10	23107000030303	7500
23011	442	57	10	44	28	30	82	10	44205700012896	9333
23012	349	48	10	44	29	30	80	10	34904800013754	9667
23013	477	71	10	44	18	19	85	10	47707100014885	9474
23021	467	52	10	44	25	28	78	10	46705200011135	8929
23022	393	57	10	44	25	25	75	10	39305700014504	10000
23023	389	51	10	44	23	31	76	10	38905100013111	7419
23031	385	47	10	44	19	23	89	10	38504700012208	8261
23032	348	60	10	44	25	25	96	10	34806000017241	10000
23033	373	73	10	44	13	21	95	10	37307300019571	6190
23041	448	48	10	44	20	19	78	10	44804800010714	10526
23042	313	47	10	44	13	19	77	10	31304700015016	6842
23043	357	54	10	44	09	12	68	09	35705400015126	7500
23051	437	47	10	44	14	28	78	10	43704700010755	5000
23052	389	66	10	44	24	33	78	10	38906600016967	7273
23053	410	54	10	44	10	23	79	10	41005400013171	4348
24111	332	44	10	44	28	31	74	10	33204400013253	9032
24112	295	47	10	44	19	28	74	10	29504700015932	6786
24113	377	57	10	43	11	20	72	10	37705700015119	5500
24131	278	48	10	44	19	36	71	10	27804800017266	5278
24132	308	52	10	44	18	34	73	10	30805200016883	5294
24133	342	55	10	44	26	36	75	10	34205500016082	7222
24141	287	41	10	44	20	27	61	10	28704100014286	7407
24142	247	41	10	44	13	23	61	10	24704100016599	5652
24143	305	44	10	44	06	15	63	10	30504400014426	4000
24151	308	49	10	44	14	31	76	10	30804900015909	4516
24152	314	42	10	44	08	29	72	10	31404200013376	2759

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
24153	364	46	10	44	07	24	70	10	36404600012637	2917
24211	336	51	10	33	17	16	84	10	33605100015179	10625
24212	348	60	10	33	12	17	80	10	34806000017241	7059
24213	259	50	10	32	19	19	77	10	25905000019305	10000
24221	279	43	10	44	29	35	72	10	27904300015412	8286
24222	288	46	10	44	26	36	71	10	28804600015972	7222
24223	235	44	10	44	22	24	68	10	23504400018723	9167
24231	291	42	10	44	06	15	41	05	29104200014433	4000
24232	306	43	10	44	14	18	64	08	30604300014052	7778
24233	198	43	10	44	12	15	60	08	19804300021717	8000
24241	278	52	10	44	21	34	75	10	27805200018705	6176
24242	275	43	10	44	32	40	73	10	27504300015636	8000
24243	237	47	10	42	23	28	76	10	23704700019831	8214
24251	358	64	10	44	27	31	70	10	35806400017877	8710
24252	331	48	10	44	18	23	73	10	33104800014502	7826
24253	236	47	10	44	16	23	72	10	23604700019915	6957
24411	159	43	10	44	19	30	64	10	15904300027044	6333
24412	179	42	10	44	22	27	71	10	17904200023464	8148
24413	218	75	10	44	23	29	72	10	21807500034404	7931
24421	195	58	10	24	06	11	57	08	19505800029744	5455
24422	209	39	10	24	13	17	70	10	20903900018660	7647
24423	270	40	10	24	16	19	71	10	27004000014815	8421
24431	152	59	10	44	26	37	68	10	15205900035816	7027
24432	190	47	10	44	30	40	68	10	19004700024737	7500
24433	254	59	10	44	22	37	70	10	25405900023228	5946
24441	287	69	10	33	11	19	76	10	28706900024042	5789
24442	348	56	10	33	18	25	75	10	34805600016092	7200
24443	336	63	10	33	13	24	77	10	33606300019750	5417
24451	199	42	10	15	15	15	64	10	19904200021106	10000
24452	217	39	10	14	08	11	61	09	21703900017972	7273
24453	241	66	10	14	09	11	62	10	24106600027386	8182
24511	186	39	10	35	31	32	61	09	18603900026958	9688
24512	203	38	10	35	30	33	76	10	20303800016719	9091
24513	227	48	10	34	26	30	69	10	22704800021145	8667
24521	246	45	10	44	31	41	61	09	24604500018293	7561
24522	224	43	10	44	36	41	66	10	22404300019196	8780
24523	232	48	10	44	31	40	71	10	23204800020690	7750
24531	209	56	10	44	22	35	62	09	20905600028794	6286
24532	267	53	10	44	38	41	69	10	26705300019850	9268
24533	220	59	10	43	31	37	71	10	22005900026318	8378
24541	281	50	10	44	42	42	62	09	28105000017794	10000
24542	320	55	10	44	38	39	72	10	32005500017188	9744
24543	285	48	10	43	42	42	65	10	28504800016842	10000
24551	274	50	10	44	28	37	61	09	27405000018248	7568
24552	269	47	10	44	33	40	66	10	26904700017472	8250
24553	285	56	10	44	20	38	72	10	28505600019649	5263
32711	389	58	10	44	30	35	81	10	38905800014910	8571
32712	352	51	10	44	27	36	76	10	35205100014489	7500
32713	326	48	10	44	29	34	74	10	32604800014724	8529
32721	364	52	10	44	24	23	74	10	36405200014286	10435

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
32722	323	47	10	44	30	33	75	10	32304700014551	9091
32723	332	43	10	44	34	33	74	10	33204300012952	10303
32731	343	54	10	44	32	38	77	10	34305400015743	8421
32732	292	48	10	44	25	39	74	10	29204800016438	6410
32733	320	51	10	44	31	33	76	10	32005100015938	9394
32741	299	48	10	44	23	32	74	10	29904800013054	7188
32742	248	33	10	44	10	32	69	10	24803300013306	3125
32743	290	39	10	44	21	35	78	10	29003900013448	6000
32751	268	48	10	44	27	33	71	10	26804800017910	8182
32752	239	43	10	44	31	35	68	10	23904300017992	8657
32753	281	41	10	44	30	32	72	10	28104100014591	9375
32811	138	44	10	44	37	40	66	10	13804400031884	9250
32812	093	42	10	44	35	40	61	10	9304200045161	8750
32813	106	39	10	42	34	36	63	10	10603900036792	9444
32821	200	50	10	44	38	39	75	10	20005000025000	9744
32822	116	40	10	44	34	36	67	10	11604000034483	9444
32823	139	58	10	37	28	36	76	10	13905800041727	7778
32831	160	42	10	44	45	45	68	10	16004200026250	10000
32832	137	54	10	44	40	44	66	10	13705400039416	9091
32833	134	42	10	42	40	41	66	10	13404200031343	9756
32841	146	38	10	44	39	40	58	10	14603800026027	9750
32842	092	37	10	44	32	42	63	10	9203700040217	7619
32843	139	62	10	43	37	40	58	10	13906200044604	9250
32851	210	40	10	44	40	40	62	10	21004000019048	10000
32852	146	45	10	44	38	39	65	10	14604500030822	9744
32853	215	50	10	44	37	42	65	10	21505000023256	8810
34311	175	51	10	44	34	37	84	10	17505100029143	9189
34312	162	46	10	44	30	33	80	10	16204600028395	9091
34313	154	48	10	44	22	27	76	10	15404800031169	8148
34321	179	44	10	44	28	35	65	10	17904400024581	8000
34322	146	48	10	44	26	32	72	10	14604800032877	8125
34323	138	45	10	44	28	31	71	10	13804500032609	9032
34331	173	43	10	44	24	37	81	10	17304300024855	6486
34332	150	41	10	44	20	35	75	10	15004100027333	5714
34333	158	41	10	44	34	37	75	10	15804100025949	9189
34341	113	31	10	44	29	33	74	10	11303100027434	8788
34342	113	42	10	44	31	34	75	10	11304200037168	9118
34343	101	43	10	44	31	37	76	10	10104300042574	8378
34351	197	43	10	44	36	37	66	10	19704300021827	9730
34352	113	36	10	44	41	43	71	10	11303600031858	9535
34353	138	48	10	44	37	38	73	10	13804800034783	9737
34611	118	51	10	44	35	35	74	10	11805100043220	10000
34612	086	42	10	44	26	26	81	10	8604200048837	10000
34613	103	54	10	43	24	24	76	10	10305400052427	10000
34621	145	53	10	44	38	38	74	10	14505300036552	10000
34622	097	61	10	44	37	37	72	10	9706100062887	10000
34623	094	44	10	42	34	36	69	10	9404400046809	9444
34631	176	48	10	44	39	41	74	10	17604800027273	9512
34632	124	59	10	44	29	35	70	10	12405900047581	8286

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
34633	174	59	10	42	26	29	72	10	17405900033908	8966
34641	196	46	10	44	35	36	73	10	19604600023469	9722
34642	113	42	10	44	37	39	69	10	11304200037168	9487
34643	115	52	10	43	33	34	74	10	11505200045217	9706
34651	153	43	10	44	24	35	73	10	15304300026105	6357
34652	140	55	10	44	29	41	71	10	14005500035286	7073
34653	115	44	10	43	17	32	70	10	11504400038261	5313
34711	088	78	10	44	20	25	69	10	8807800088636	8000
34712	078	54	10	44	23	29	65	10	7805400069231	7931
34713	123	68	10	44	26	28	64	10	12306800055285	9286
34721	154	64	09	30	09	10	63	09	17117111141558	9000
34722	154	58	10	30	17	17	67	10	15405800037662	10000
34723	118	49	09	29	11	09	43	06	13115444441525	12222
34731	015	14	02	16	06	03	11	02	7507000093333	20000
34732	040	22	06	16	07	07	35	06	6673666755000	10000
34733	027	18	03	16	05	03	14	02	9006000066667	16667
34741	116	78	10	30	20	20	61	10	11607800067241	10000
34742	116	53	10	29	23	23	65	10	11605300045690	10000
34743	137	52	10	29	22	36	66	10	13705200037956	6111
34751	093	67	10	21	07	10	37	06	9306700072043	7000
34752	084	47	10	21	14	16	60	10	8404700055952	8750
34753	099	55	10	20	13	13	64	10	9905500055556	10000
34841	172	75	10	44	37	38	66	10	17207500043605	9737
34842	113	52	10	44	37	37	69	10	11305200046018	10000
34843	107	50	10	44	35	37	66	10	10705000046729	9459
34851	124	76	10	44	43	43	62	10	12407600061290	10000
34852	138	55	10	44	42	42	63	10	13805500039855	10000
34853	172	70	10	44	40	41	65	10	17207000040698	9756
34911	207	64	10	44	33	33	63	10	20706400030918	10000
34912	103	60	10	44	23	24	65	10	10306000056252	9583
34913	137	62	10	37	22	24	67	10	13706200045255	9167
34921	132	55	10	44	29	35	64	10	13205500041667	8286
34922	106	54	10	44	24	29	65	10	10605400050943	8276
34923	103	48	10	43	27	27	65	10	10304800046602	10000
34931	158	58	10	44	23	28	65	10	15805800036709	8214
34932	173	52	10	44	28	34	69	10	17305200030058	8235
34933	171	69	10	44	27	25	71	10	17106900040351	10800
34941	160	55	10	44	25	29	55	10	16005500034375	8621
34942	092	56	10	44	22	30	59	10	9205600060870	7333
34943	081	50	10	43	29	34	62	10	8105000061728	8529
34951	161	38	10	44	24	37	66	10	16103800023602	6486
34952	094	32	10	44	17	39	67	10	9403200034043	4359
34953	151	49	10	43	21	33	70	10	15104900032450	6364
35011	042	21	05	44	04	05	20	03	8404200050000	8000
35012	102	41	07	44	02	06	39	06	14575857140196	3333
35013	031	22	03	44	04	04	20	03	10337333370968	10000
35021	179	52	10	44	25	35	70	10	17905200029050	7143
35022	141	47	10	44	31	41	68	10	14104700033333	7561
35023	125	55	10	44	18	38	69	10	12505500044000	4737

Appendix Table 3 continued

1	2	3	4	5	6	7	8	9	10	11
35031	105	62	10	44	21	28	68	10	10506200059048	7500
35032	084	40	10	44	26	35	74	10	8404000047619	7429
35033	125	50	10	44	25	30	68	10	12505000040000	8333
35041	121	57	10	44	16	19	73	10	12105700047107	8421
35042	121	50	10	44	24	26	72	10	12105000041322	9231
35043	122	56	10	43	24	27	66	10	12205600045902	8889
35051	130	50	10	44	40	42	64	10	13005000038462	9524
35052	108	43	10	44	36	40	67	10	10804300039815	9000
35053	098	54	10	44	35	43	68	10	9805400055102	8140
35321	134	65	10	31	12	11	62	10	13406500048507	10909
35322	104	63	10	30	17	20	62	10	10406300060577	8500
35323	110	65	07	30	10	07	38	06	15719235759091	14286
35341	026	14	02	04	02	03	11	02	13007000053846	6667
35342	027	17	03	04	04	04	18	03	9005666762963	10000
35343	055	23	03	04	03	03	17	03	133376666741813	10000
35351	100	64	07	21	09	08	42	07	14299142964000	11250
35352	079	34	08	21	07	09	43	07	9884250043038	7778
35353	033	22	03	20	03	02	18	03	11007333366667	15000

BIOGRAPHICAL SKETCH

Anthony E. Squillace was born September 16, 1915, at Kinney, Minnesota. In June, 1933, he was graduated from Martin Hughes High School. After 3 years of temporary employment with the Civilian Conservation Corps and U.S. Forest Service, he resumed schooling at the Virginia Junior College, and University of Minnesota, earning a Bachelor of Science degree in Forestry from the latter in 1940. From 1940 to 1942 he was employed by the Consolidated Water Power and Paper Company at Grand Marais, Minnesota. From 1943 to 1945 he served with the U.S. Army in the United States and Europe. In 1946 he began permanent employment with the U.S. Forest Service, serving as Research Forester at stations in Montana, Washington, and Florida, and, aside from interruptions for further schooling, has continued in this position to the present time. He obtained a Master of Science degree in Forestry and Botany at the University of Montana in 1955, and enrolled in the Graduate School of the University of Florida in 1960.

Anthony E. Squillace is married to the former Dorothy Alice Babbini and is the father of three children. He is a member of the Society of American Foresters, Xi Sigma Pi, Phi Sigma, and Gamma Sigma Delta.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Agriculture and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

April 18, 1964

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